COLLEGE OF ST. SCHOLASTICA
629.13 Y2
Yancey, Lewis A - Aerial navigation and meteorology
3 0116 00007 9811

AERIAL NAVIGATION AND METEOROLOGY

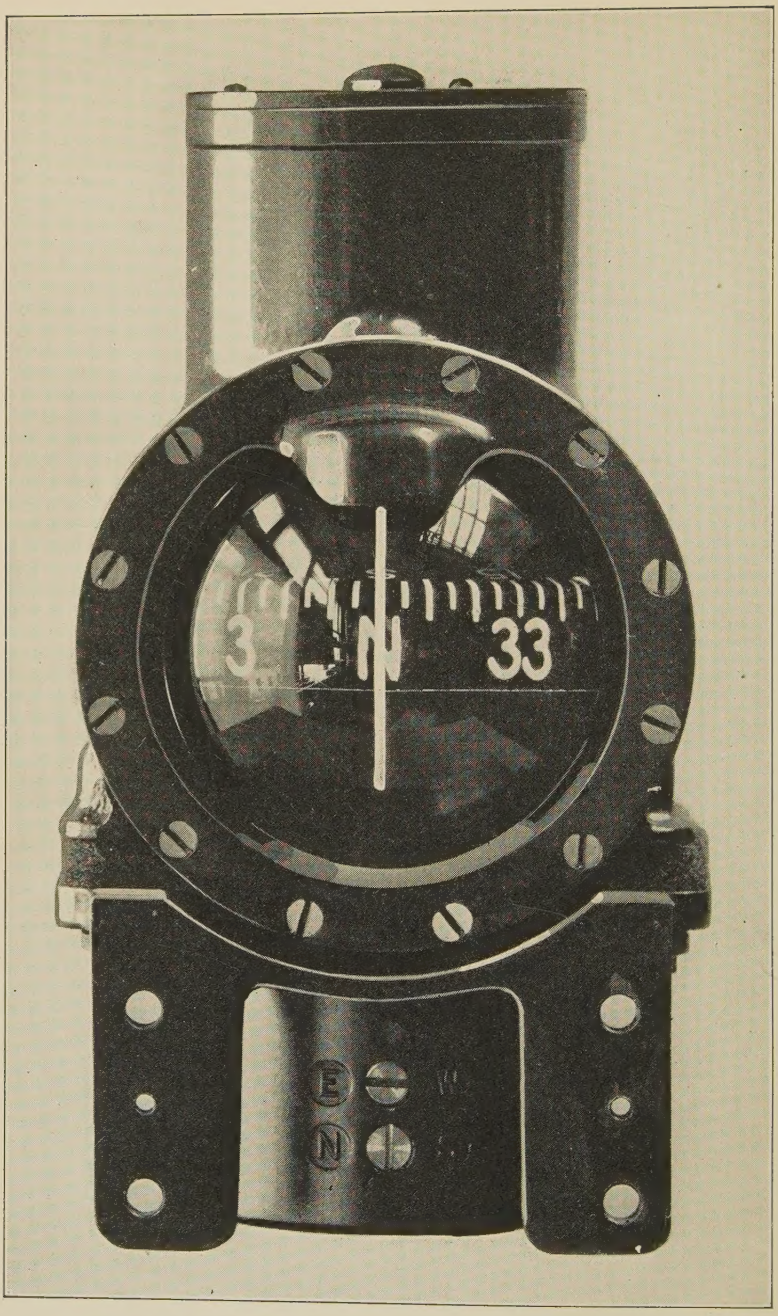
YANCEY

WITHDRAWN
LIBRARY
College of St. Scholastica
DULUTH, MINN.

Digitized by the Internet Archive
in 2025

https://archive.org/details/bwb_C0-CCK-933

AERIAL NAVIGATION
AND
METEOROLOGY



Magnetic Compass

AERIAL NAVIGATION AND METEOROLOGY

A COMPREHENSIVE TREATISE IN SIMPLE LANGUAGE FOR THE STUDENT WITH AN AVERAGE EDUCATION

BY

CAPTAIN LEWIS A. YANCEY

Master Mariner (Unlimited)
Marine Surveyor Nautical Counselor

CONTAINS NUMEROUS SOLVED PROBLEMS AND EXAMPLES FOR PRACTICE

Second Revised and Much Enlarged Edition

Fully Illustrated by 102 Engravings and Colored Plates

NEW YORK
THE NORMAN W. HENLEY PUBLISHING CO.
2 WEST 45TH STREET
1929

LIBRARY
College of St. Scholastica

Copyright, 1927, by
Captain Lewis A. Yancey
Copyright, 1929, by
The Norman W. Henley Publishing Company

MOST OF THE ILLUSTRATIONS IN THIS BOOK HAVE BEEN SPECIALLY MADE BY THE PUBLISHERS AND THEIR USE WITHOUT PERMISSION IS STRICTLY PROHIBITED

PRINTED IN UNITED STATES OF AMERICA

PREFACE

There seem to be few books written by experienced navigators in such simple language that the average man might understand and appreciate the information given. Most publications on navigation are either far too advanced, or else contain historical and personal, instead of practical reminiscences.

It has been the writer's object to produce a book from which the man of average education may obtain a good working knowledge of the elements of navigation and meteorology. It is not pretended that this work contains any literary merit whatsoever, but it is hoped that the practical and useful information contained will add something to the comfort, efficiency and safety of those who choose aviation for a career.

LEWIS A. YANCEY.

July, 1929.

22182

CONTENTS

CHAPTER I

PAGE

Bearing and Direction 1-16

CHAPTER II

The Terrestrial Sphere 17-25

CHAPTER III

Charts and Maps 26-44

CHAPTER IV

The Compass 45-58

CHAPTER V

Compass Errors 59-75

CHAPTER VI

Compass Compensation 76-100

CHAPTER VII

Correction of Courses 101-135

CHAPTER VIII

Cross-Country Work 136-162

CHAPTER IX

PAGE

Meteorology 163-203

CHAPTER X

First-Aid 204-215

CHAPTER XI

Air Commerce Regulations 216-267

APPENDIX

Examination Questions for Transport Pilots . . . 268-272

Course Error Table 273

Conversion Table Statute to Nautical Miles . . . 274

Variation Chart . . . . . *Facing page* 274

Glossary of Terms Used in Aerial Navigation and Meteorology 275-302

Index 303-316

AERIAL NAVIGATION
AND
METEOROLOGY

AERIAL NAVIGATION AND METEOROLOGY

CHAPTER I

BEARING AND DIRECTION

1. A circle is a figure bounded by a curved line, called the *circumference* or *periphery*.

2. The *diameter* of a circle is a straight line passing through the exact center and terminating at the circumference, as AB. See figure 1.

3. The *radius* of a circle is a straight line drawn from the center to the circumference, as OC. See figure 1.

4. The circumference of a circle is divided into 360 parts called degrees (°). Each degree is divided into 60 parts called minutes (′). Each minute is divided into 60 parts called seconds (″). In the plotting of courses, minutes and second are usually disregarded, the work being confined to whole degrees.

5. The graduations, or marks, of a circle start with 0° at the top and increase to the right. Thus, the graduation at point C, figure 1, which is one-quarter around the circle, is 90°. Point B is half-way around, or 180°.

6. An *angle* is the amount of divergence between two straight lines that meet at the center of a circle. It is measured by the arc of the circumference intercepted between the two lines. Thus, in figure 1, the angle between lines OC and OA is 90°, or one-quarter of the circumference.

7. A *protractor* is an instrument for the measurement of angles. There are several different forms and models obtainable, but the

most satisfactory type for the navigator is one made in the form of half a circle, preferably of transparent celluloid, with small marks showing each degree, larger marks every fifth degree and numbers every 10 degrees. Such an instrument may be obtained at any stationery store for from twenty-five to fifty cents.

8. To measure an angle with any type protractor, simply place the central mark on the spot where the lines intersect and note the

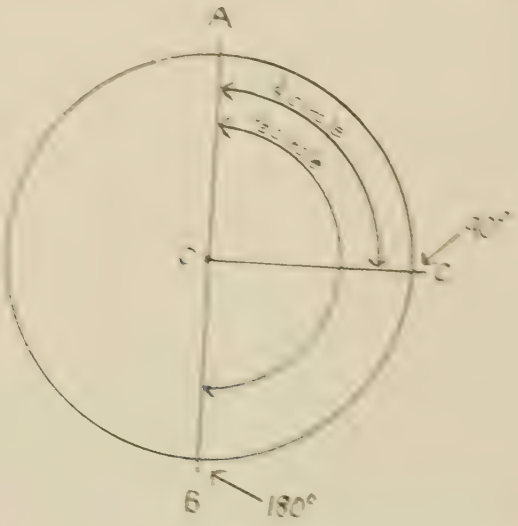


FIG. 1

number of degrees contained in the arc of the graduated circumference. Thus, in figure 2, the angle between line OA and line OB is found to be 80°, between line OA and line OC is 140°, between line OB and line OC, 60°.

9. The apparent line where the earth and the sky join, which seems to encircle the observer having an unobstructed view, is known as the *horizon*, and for the purpose of indicating direction it is considered a circle with the observer at the center.

10. For the purpose of indicating any desired direction, compass points or directions are used. The principal points of the com-

pass are north, east, south and west. The spaces between the principal, or cardinal points as they are sometimes called, are divided into eight equal parts, making the whole circumference of the horizon contain thirty-two points, each of which has a separate name. Naming the points of the compass in their regu-

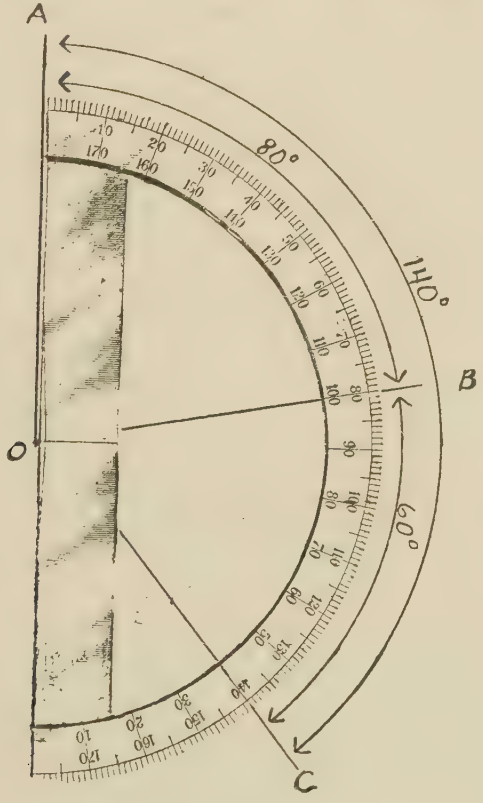


FIG. 2

lar sequence is called *boxing the compass.* While compass points are seldom used in *aerial navigation,* they are frequently met with in the study of meteorological data.

11. The horizon, in addition to being divided into points, is also divided into three hundred and sixty degrees (360°), so any desired direction may be expressed in degrees as well as points.

12. Figure 3 is a graphic representation of the horizon showing both the points (divided into quarters), and degrees. It will be noted that each point is equal to 11¼°. The compass is boxed as follows: north, north-by-east, north-northeast, northeast-by-north, northeast, northeast-by-east, east-northeast, east-by-north, east, east-by-south, east-southeast, southeast-by-east, southeast, southeast-by-south, south-southeast, south-by-east, south, south-

FIG. 3

by-west, south-southwest, southwest-by-south, southwest, southwest-by-west, west-southwest, west-by-south, west, west-by-north, west-northwest, northwest-by-west, northwest, northwest-by-north, north-northwest, north-by-west, north.

13. The following table gives the corresponding direction in degrees for any compass direction.

14. The *bearing* of an object is the direction the object is from the observer and may be referred to in points or degrees. Strictly speaking, it is the angle between the north-and-south line and a line from the observer to the object. Thus, in figure 4, point A bears north, or 0° (zero), as the angle between the north-

Conversion of Compass Points into Corresponding Readings of the New Compass Card

Compass Points	New Card	Compass Points	New Card
N. ¼ E.	2° 48′ 45″	S. ¼ W.	182° 48′ 45″
N. ½ E.	5° 37′ 30″	S. ½ W.	185° 37′ 30″
N. ¾ E.	8° 26′ 15″	S. ¾ W.	188° 26′ 15″
N. by E.	11° 15′ 0″	S. by W.	191° 15′ 0″
N. by E. ¼ E.	14° 3′ 45″	S. by W. ¼ W.	194° 3′ 45″
N. by E. ½ E.	16° 52′ 30″	S. by W. ½ W.	196° 52′ 30″
N. by E. ¾ E.	19° 41′ 15″	S. by W. ¾ W.	199° 41′ 15″
N. N. E.	22° 30′ 0″	S. S. W	202° 30′ 0″
N. N. E. ¼ E.	25° 18′ 45″	S. S. W. ¼ W.	205° 18′ 45″
N. N. E. ½ E.	28° 7′ 30″	S. S. W. ½ W.	208° 7′ 30″
N. N. E. ¾ E.	30° 56′ 15″	S. S. W. ¾ W.	210° 56′ 15″
N. E. by N.	33° 45′ 0″	S. W. by S.	213° 45′ 0″
N. E. ¾ N.	36° 33′ 45″	S. W. ¾ S.	216° 33′ 45″
N. E. ½ N.	39° 22′ 30″	S. W. ½ S.	219° 22′ 30″
N. E. ¼ N.	42° 11′ 15″	S. W. ¼ S.	222° 11′ 15″
N. E.	45° 0′ 0″	S. W.	225° 0′ 0″
N. E. ¼ E.	47° 48′ 45″	S. W. ¼ W.	227° 48′ 45″
N. E. ½ E.	50° 37′ 30″	S. W. ½ W.	230° 37′ 30″
N. E. ¾ E.	53° 26′ 15″	S. W. ¾ W.	233° 26′ 15″
N. E. by E.	56° 15′ 0″	S. W. by W.	236° 15′ 0″
N. E. by E. ¼ E.	59° 3′ 45″	S. W. by W. ¼ W.	239° 3′ 45″
N. E. by E. ½ E.	61° 52′ 30″	S. W. by W. ½ W.	241° 52′ 30″
N. E. by E. ¾ E.	64° 41′ 15″	S. W. by W. ¾ W.	244° 41′ 15″
E. N. E.	67° 30′ 0″	W. S. W.	247° 30′ 0″
E. N. E. ¼ E.	70° 18′ 45″	W. S. W. ¼ W.	250° 18′ 45″
E. N. E. ½ E.	73° 7′ 30″	W. S. W. ½ W.	253° 7′ 30″
E. N. E. ¾ E.	75° 56′ 15″	W. S. W. ¾ W.	255° 56′ 15″
E. by N.	78° 45′ 0″	W. by S.	258° 45′ 0″
E. ¾ N.	81° 33′ 45″	W. ¾ S.	261° 33′ 45″
E. ½ N.	84° 22′ 30″	W. ½ S.	264° 22′ 30″
E. ¼ N.	87° 11′ 15″	W. ¼ S.	267° 11′ 15″
East	90° 0′ 0″	West	270° 0′ 0″
E. ¼ S.	92° 48′ 45″	W. ¼ N.	272° 48′ 45″
E. ½ S.	95° 37′ 30″	W. ½ N.	275° 37′ 30″
E. ¾ S.	98° 26′ 15″	W. ¾ N.	278° 26′ 15″
E. by S.	101° 15′ 0″	W. by N.	281° 15′ 0″
E. S. E. ¾ E.	104° 3′ 45″	W. N. W. ¾ W.	284° 3′ 45″
E. S. E. ½ E.	106° 52′ 30″	W. N. W. ½ W.	286° 52′ 30″
E. S. E. ¼ E.	109° 41′ 15″	W. N. W. ¼ W.	289° 41′ 15″
E. S. E.	112° 30′ 0″	W. N. W.	292° 30′ 0″
S. E. by E. ¾ E.	115° 18′ 45″	N. W. by W. ¾ W.	295° 18′ 45″
S. E. by E. ½ E.	118° 7′ 30″	N. W. by W. ½ W.	298° 7′ 30″
S. E. by E. ¼ E.	120° 56′ 15″	N. W. by W. ¼ W.	300° 56′ 15″
S.E. by E.	123° 45′ 0″	N. W. by W.	303° 45′ 0″
S. E. ¾ E.	126° 33′ 45″	N. W. ¾ W.	306° 33′ 45″
S. E. ½ E.	129° 22′ 30″	N. W. ½ W.	309° 22′ 30″
S. E. ¼ E.	132° 11′ 15″	N. W. ¼ W.	312° 11′ 15″
S. E.	135° 0′ 0″	N. W.	315° 0′ 0″
S. E. ¼ S.	137° 48′ 45″	N. W. ¼ N.	317° 48′ 45″
S. E. ½ S.	140° 37′ 30″	N. W. ½ N.	320° 37′ 30″
S. E. ¾ S	143° 26′ 15″	N. W. ¾ N.	323° 26′ 15″
S. E. by S.	146° 15′ 0″	N. W. by N.	326° 15′ 0″
S. S. E. ¾ E.	149° 3′ 45″	N. N. W. ¾ W.	329° 3′ 45″
S. S. E. ½ E.	151° 52′ 30″	N. N. W. ½ W.	331° 52′ 30″
S. S. E. ¼ E.	154° 41′ 15″	N. N. W. ¼ W.	334° 41′ 15″
S. S. E.	157° 30′ 0″	N. N. W.	337° 30′ 0″
S. by E. ¾ E.	160° 18′ 45″	N. by W. ¾ W.	340° 18′ 45″
S. by E. ½ E.	163° 7′ 30″	N. by W. ½ W.	343° 7′ 30″
S. by E. ¼ E.	165° 56′ 15″	N. by W. ¼ W.	345° 56′ 15″
S. by E.	168° 45′ 0″	N. by W.	348° 45′ 0″
S. ¾ E.	171° 33′ 45″	N. ¾ W.	351° 33′ 45″
S. ½ E.	174° 22′ 30″	N. ½ W.	354° 22′ 30″
S. ¼ E.	177° 11′ 15″	N. ¼ W.	357° 11′ 15″
South	180° 0′ 0″	North	360° 0′ 0″

and-south line and a line from the observer (at o) to the object is zero degrees. Point B bears east, or 90°, that is, the angle between the north-and-south line and a line from the observer to the object is 90°. Likewise, point C bears 270°, or west. In connection with the bearing of point C some confusion may arise as how the angle between the north and south line and a line from

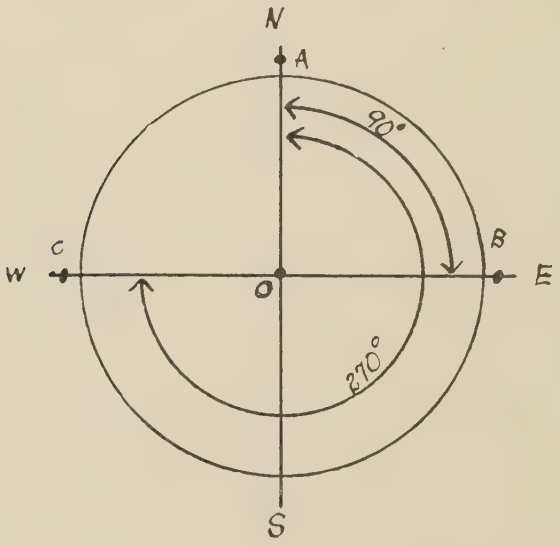


Fig. 4

the observer to point C could exceed 90°, and it may be well to get the point clear at once, as a great deal of difficulty will be avoided later on.

15. The present system of graduating the horizon from 0° to 360° (known as clockwise graduations) is of comparative recent origin, and prior to its inception, all bearings were referred to the north or south points. Thus, a point bearing northwest was referred to as north 45° west, the angle between the north and south line and the line of bearing being 45°; southwest, as south 45° west; north, south, east and west were always referred

to by name. Under the old system, north and south were zero points, while east and west were 90° points. All bearings were given as north or south X° east or west, as the case happened to be. With the advent of clockwise graduations north became 0° or 360°, east 90°, south 180° and west 270°.

16. In figure 5, point A bears northeast, as the angle between the north and south line, NS, and a line from the observer to

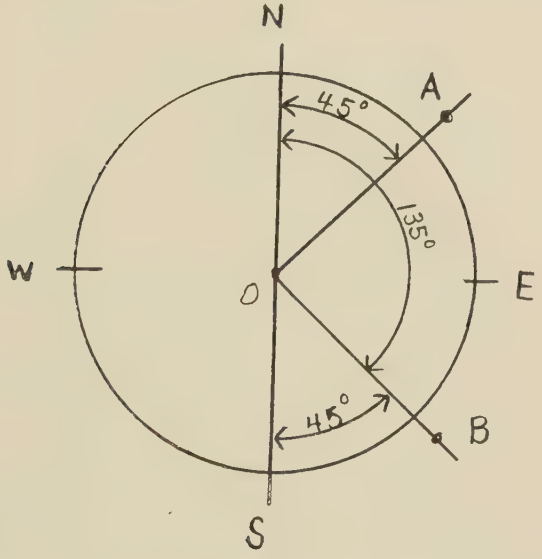


FIG. 5

the point, OA, is 45°. Under the old system, the bearing would be north 45° east, while with clockwise graduations it is simply 45°. Point B bears southeast, or, under the old graduations, south 45° east, which is 135° clockwise.

17. A careful study of the following worked out examples should make the subject clear. Bear in mind that north is 360° or 0°, and south is 180°. The figure is a circle representing the horizon and should be referred to constantly. The position of the observer is always at the center of the circle.

Example 1. The bearing of a point is southeast. What is this in degrees by both the old and new system of graduations?

Solution, see figure 6.

(a) Southeast = S. 45° E.
(b) Southeast = 180° − 45° = 135° ans.

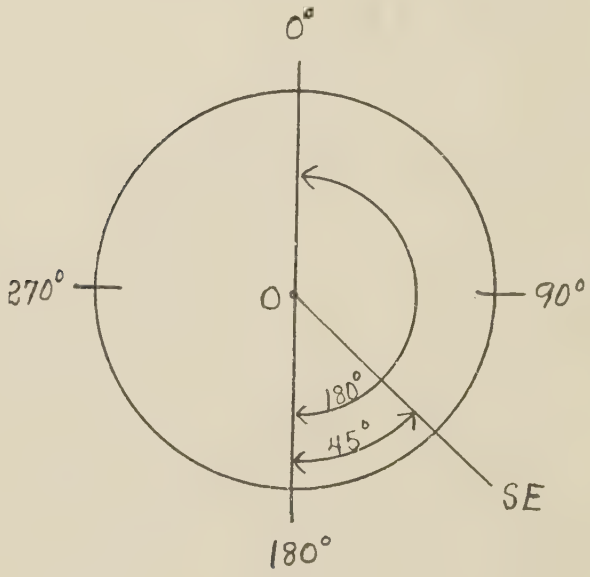


Fig. 6

Example 2. The bearing of a point is south 30° west. What is this by clockwise graduations?

Solution, see figure 7.

South = 180°.
180° + 30° = 210° ans.

Example 3. The bearing of a point is south 30° east. What is this by clockwise graduations?

Solution, see figure 8.

South or 180° − 30° = 150° ans.

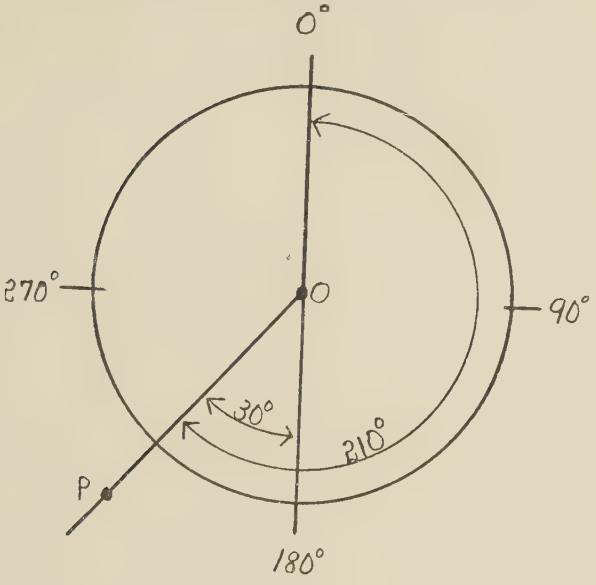


FIG. 7

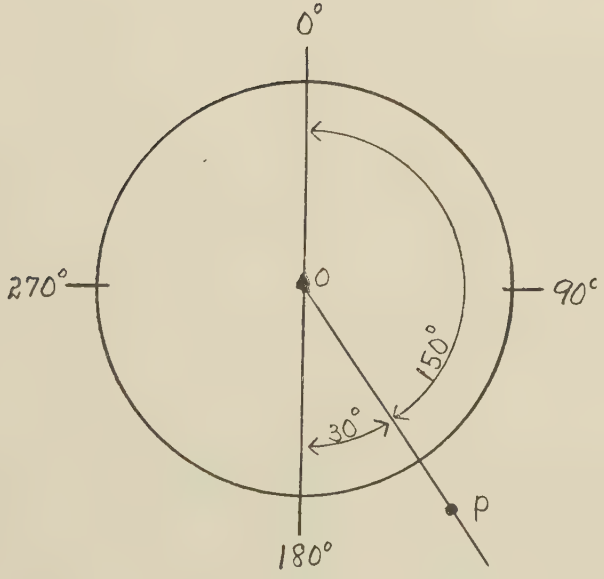


FIG. 8

Example 4. The bearing of point A is north 15° west. What is this by clockwise graduations?

Solution, see figure 9.

North or 360° — 15° = 345° ans.

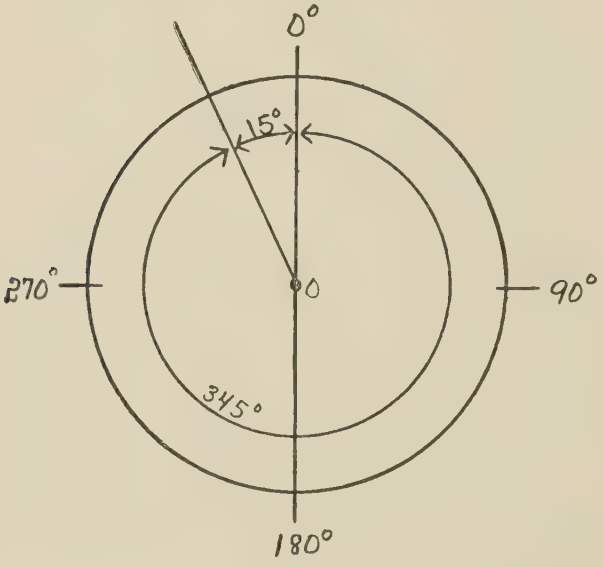


FIG. 9

Example 5. The weather forecast indicates that winds from west-southwest may be expected. What direction is this in degrees, using clockwise graduations?

Solution, see figure 10.

Consulting the table in paragraph No. 5, we find
W.S.W. = 247.5° ans.

Example 6. An observer finds the wind blowing from the northwest. After a brief interval, a second observation is taken and the wind is found to have shifted 60° to the left. What direction is it now blowing?

Solution, see figure 11.

Northwest or 315° — 60° = 255° ans.

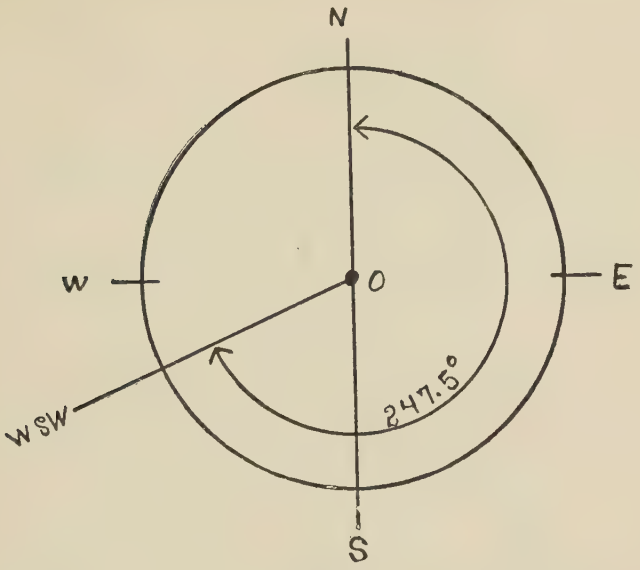


FIG. 10

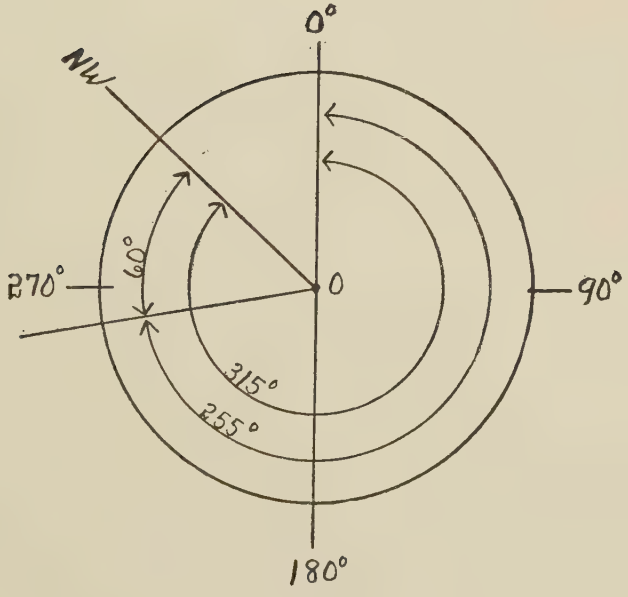


FIG. 11

Example 7. The bearing of field A from field B is 5° west of north. What is the bearing of field B from field A by both the old and new graduations?

Solution, see figure 12.

Bearing of field A from field B, N. 5° W. Reversing this, the bearing of field B from field A is S. 5° E., or,

$$180° - 5° = 175°, \text{ or N. } 5° \text{ W} = 355° - 180° = 175° \text{ ans.}$$

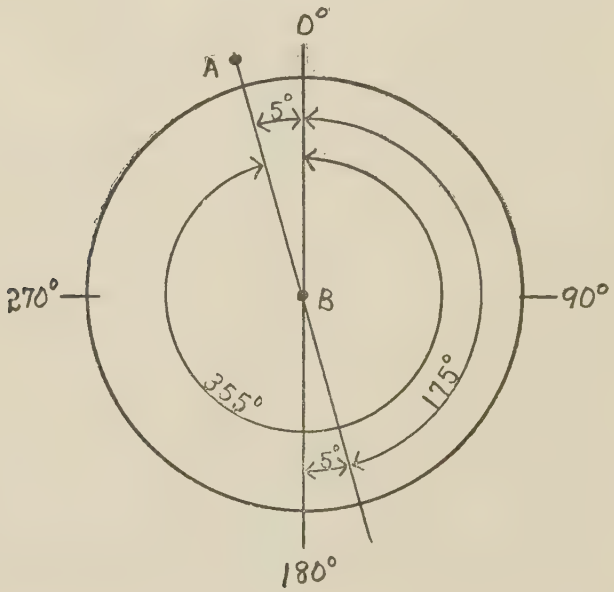


Fig. 12

18. Bearings that refer exclusively to the direction in which the plane is heading are known as *relative bearings*, and may be referred to either in points or degrees. Referring to figure 13, the relative bearing of a point directly ahead is called *dead ahead*, while a point directly astern is *dead astern*. Point B is broad on the starboard bow; point C is on the starboard beam; point D is broad on the starboard quarter. Beginning from dead ahead, the relative bearings in points are as follows:

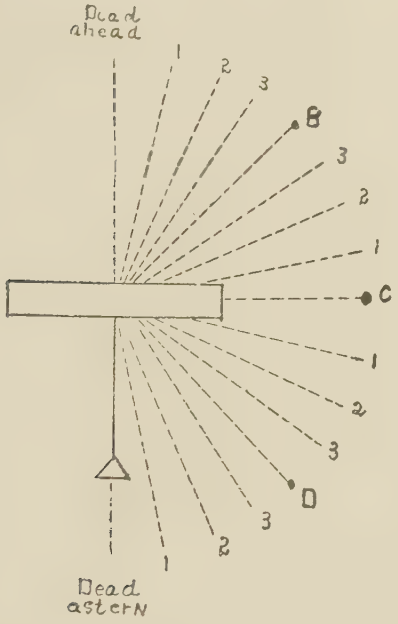


FIG. 13

Dead ahead
1 point on the stardboard bow
2 points on the starboard bow
3 points on the starboard bow
Broad on the starboard bow
3 points forward of the starboard beam
2 points forward of the starboard beam
1 point forward of the starboard beam
On the starboard beam (or abeam)
1 point abaft the starboard beam
2 points abaft the starboard beam
3 points abaft the starboard beam
Broad on the starboard quarter
3 points on the starboard quarter
2 points on the starboard quarter
1 point on the starboard quarter
Dead astern

The bearings on the left, or port side, are designated in the same way, the word port being used instead of starboard.

19. When relative bearings are given in degrees, dead ahead and dead astern being 0°, are referred to by their regular names; the port and starboard beam are 0° points referred to by their regular names; the port and starboard bow and port and starboard quar-

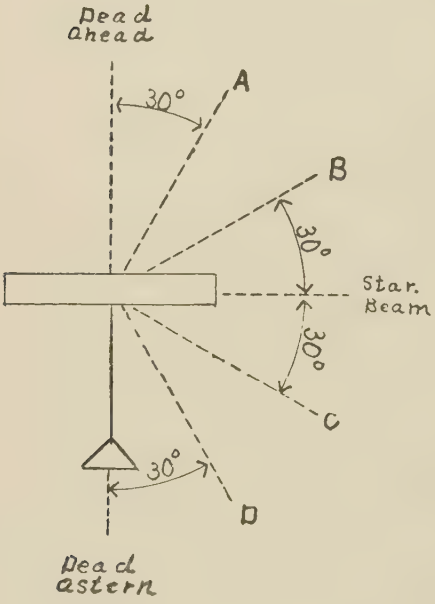


FIG. 14

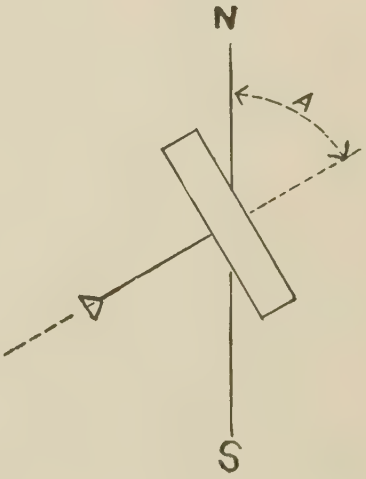


FIG. 15

ter are 45° points and referred to by their regular names. Thus, in figure 14, point A would be 30° on the starboard bow; point B 30° forward of the starboard beam; point C 30° abaft the starboard beam; point D 30° on the starboard quarter.

20. The particular direction in which the plane is being steered is called the *course*. Technically, it is the angle the fore-and-aft line of the plane makes with the north-and-south line, and is sometimes referred to as the *course angle*. An imaginary line,

running through the exact center of the ship, from the propeller hub to the leading edge of the fin, would be the fore-and-aft line. In figure 15, A is the course angle.

EXAMPLES FOR PRACTICE

NOTE: A rough sketch should be made of each example. This will greatly assist in obtaining a clear mental picture of the entire situation.

Example 1. From field A, field B bears north, and field C bears 320°. If two ships take off from field A, one bound for field B and one bound for field C, what is the difference in their courses?

Answer, 40°.

Example 2. The wind is blowing from the northeast. What is (a) the relative direction of the wind on the plane bound to field B? (b) on the plane bound to field C?

Answer, (a) Broad on the starboard bow. (b) 5° forward of the starboard beam.

Example 3. A plane steering 230° received word by radio that a strong west-north-west (W.N.W.) wind may be expected. If the ship continues on her course (230°), what will the relative direction of the expected wind be?

Answer, 27.5° forward of the starboard beam.

Example 4. A plane bound from Philadelphia, Pennsylvania, to Boston, Massachusetts, steered 75°. What is the course back to Philadelphia?

Answer, 255°.

Example 5. A plane bound from field A to field B steered 350°. The correct bearing of field B from field A was 17° west of north. How much was the course in error? What was the correct course?

Answer, Error, 7° to the right. Correct course, 343°.

CHAPTER II

THE TERRESTRIAL SPHERE

1. The *axis of the earth* is a straight line passing through the center of the earth between the poles. It is the diameter around which the earth revolves.

2. The *poles of the earth* are the points where the axis meets the surface. Thus, in figure 16, P is the north pole and P′ the south pole. The straight line between the two poles, which passes through the center of the earth, is the axis.

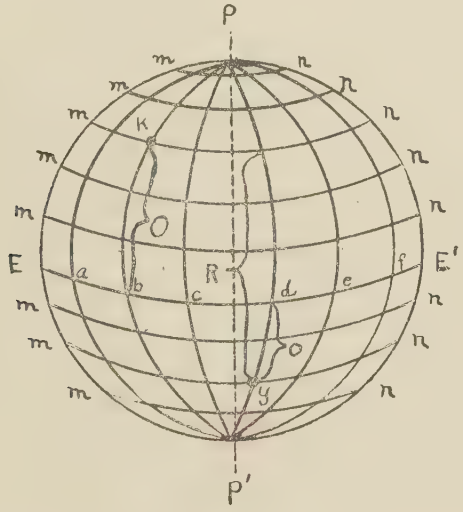


Fig. 16

3. A *great circle* is a circle on the earth's surface whose plane *passes through the center* and divides the earth in two equal parts. A small circle is a circle on the earth's surface whose plane *does not* pass through the center of the earth.

4. The *equator* is a great circle on the earth's surface, which is

an equal distance from both poles at all points. The equator divides the earth in two equal parts called *Hemispheres*. The *northern hemisphere* is the half north of the equator, and the *southern hemisphere* is the half south of the equator. Both poles are 90° from the equator. In figure 16 E, a, b, c, d, e, F, E′, represents the equator. Being 90° from the poles at all points, the equator runs true east and west.

5. The *meridians* are great circles passing through both poles of the earth. In figure 16, PaP′, PbP′, PcP′, etc., are meridians. As all meridians pass through both poles, they run true north and south and, therefore, are perpendicular to the equator.

6. Of the infinite number of meridians that may be imagined as being drawn on the surface of the earth, one, known as the *prime* or *zero meridian,* is always selected as a point of reference. At a conference of delegates from the principal maritime nations of the world, held in Washington in 1884, the meridian passing through the Royal Observatory at Greenwich, England, was selected as the zero meridian for universal use.

7. *Latitude parallels* are small circles whose planes are parallel to the equator. In figure 16, the circles M N are latitude parallels. Being parallel to the equator, latitude parallels run east and west and at all points are an equal distance from the equator. Consequently, all places situated on the same parallel will be the same distance from the equator.

8. Like meridians, any number of latitude parallels may be imagined drawn on the earth's surface; each, a small circle parallel to the equator and, therefore, running east and west.

9. The *latitude* of any place on the earth's surface is the *angular distance north or south from the equator, measured on the meridian passing through that place.* In figure 16, the latitude of point K is the arc, or distance o, of meridian PbP′ which passes through point K. It is named north as it is north of the equator.

Likewise, the latitude of point y is the arc, or distance o of the meridian PdP′ which passes through point y. It is named south as it is south of the equator.

10. Latitude is reckoned in degrees, minutes and seconds, from the equator toward the poles. Since the poles are one-quarter of a circle, or 90°, from the equator, no latitude can exceed 90°. When on the equator, the latitude is 0°, and, when at the pole it is 90°, either north or south.

11. The *difference of latitude* between two places is the arc of the meridian contained between the parallels passing through the places. In figure 16, the difference of latitude between point K and point y is the arc of the meridian R.

12. To find the difference of latitude between two places located on the same side of the equator, subtract the lesser from the greater. If located on different sides of the equator, the difference of latitude is found by adding the two latitudes.

Example: What is the difference of latitude between New York City in latitude 40° 40′ N. and Santiago, Cuba, in latitude 20° 02′ N.?

Solution:

New York City	= 40° 40′ N.
Santiago	= 20° 02′ N.
Difference of latitude	= 20° 38′

Example: What is the difference of latitude between New York City in latitude 40° 40′ N. and Cape St. Roque, S. A., in latitude 10° 02′ S.?

Solution:

Latitude of New York	= 40° 40′ N.
Latitude of Cape St. Roque	= 10° 02′ S.
Difference of latitude	= 50° 42′

13. A *nautical mile* is equal to the mean length of a minute of latitude. It is reckoned as 6,080 feet. A statute, or land mile,

is 5,280 feet. Thus, a place situated in 10 degrees north latitude is 600 nautical miles north of the equator. ($1° = 60'$. $60 \times 10 = 600$).

14. The longitude of a point is *the distance in arc, measured on the equator, east or west from the zero meridian to the meridian passing through the point.* In figure 17 E,D,A,B,E′ represents the equator and G,C,F a latitude parallel. The arc of the equartor o, intercepted between the zero meridian and the me-

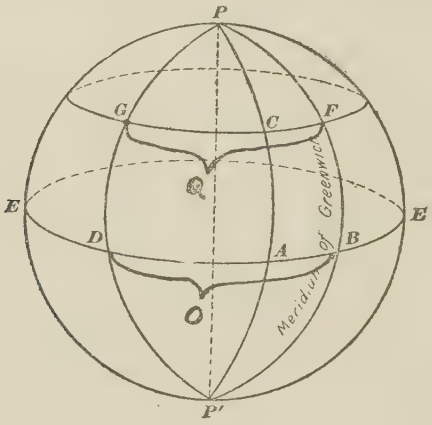


Fig. 17

ridian PDP′, is the longitude of point G. It is named west because it is west of the zero meridian.

15. Longitude is also equal to the angle subtended at the pole by the zero meridian and the meridian passing through the place. Thus, the angle F,P,G in figure 17 contains the same number of degrees, minutes and seconds as the arc of the equator o. Likewise, the arc of the parallel G,C,F and arc o of the equator contain the same number of degrees, minutes and seconds though the distance in miles is much less.

16. Longitude is reckoned from 0° to 180° east or 180° west beginning at the meridian of Greenwich (zero meridian), but is never considered more than 180°. If the result of a calculation

is a longitude exceeding 180°, it is subtracted from 360° and given the contrary name. Thus, longitude 190° west would be 360° — 190° W. = 170° East. The former expression is never used, however, and no place can exceed 180° of longitude, either east or west. Figure 18 represents a view of the earth from directly

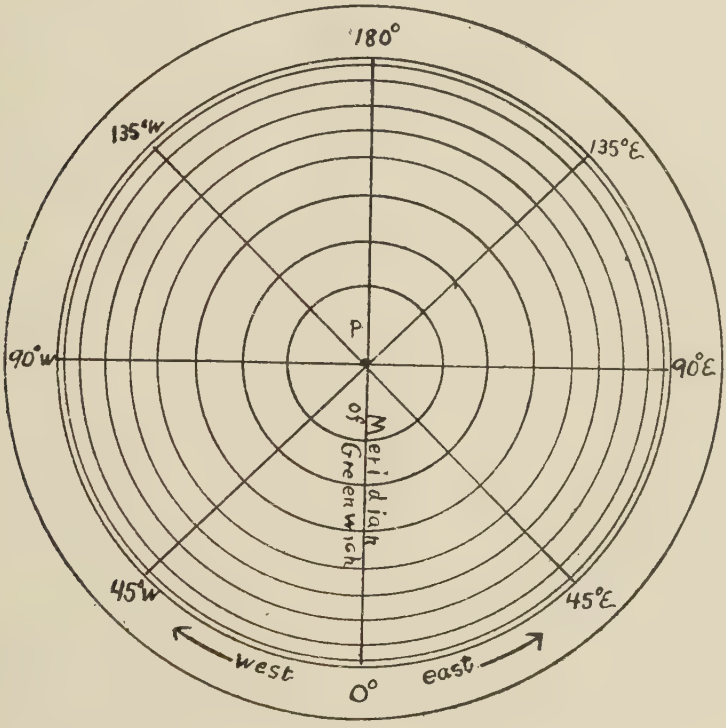


FIG. 18

above the north pole P, showing several latitude parallels which appear as circles, and showing the meridians every 45°. A careful study of this figure will illustrate the statements made above.

17. Besides being measured in degrees, minutes and seconds, longitude may also be measured in time, each hour of time being equal to 15°. This may be readily understood when we consider the sun makes a complete circuit of 360° in 24 hours. Thus,

$360 \div 24 = 15°$. In other words, in one hour of time the sun will travel 15° of longitude.

18. The instant the sun reaches its maximum altitude (it is then on the meridian of that place), it is noon, or exactly 12 o'clock for all places located on that meridian. At a place 15° east of that meridian, it will be one hour past noon. At a place 15° west, it will be one hour before noon.

19. Since longitude can be expressed in either time or arc, it is necessary to be able to convert time into arc, and arc into time.

24	hours	of	time	equal	360°	of	arc
12	"	"	"	"	180°	"	"
6	"	"	"	"	90°	"	"
3	"	"	"	"	45°	"	"
1	"	"	"	"	15°	"	"
1	minute	of	time	equals	15	minutes	of arc
1	second	"	"	"	15	seconds	" "

From an inspection of the above:

4 minutes of time equal 1° of arc
4 seconds of time equal 1 minute of arc

20. To convert time into arc:

Rule: Multiply the number of hours by 15; the result is degrees. Divide the minutes and seconds by 4, and consider every unit of the remainder as 15 minutes of arc, if minutes be divided, and as 15 seconds of arc, if seconds be divided.

Example: Convert 2h 10m 20s into arc.

Solution:

$2 \times 15 = 30°$
10m. $\div 4 = 2$ (rem. 2) $= 2° 30'$
20s. $\div 4 = 5$ (rem. 0) $= 5' 0''$

2h. 10m. 20s. $= 32° 35' 00'' =$ ans.

21. To convert arc into time:

Rule: Multiply the degrees and minutes by 4, the minutes of arc become seconds of time, and the degrees become minutes of time, which are converted to hours by dividing by 60.

Example 1. Convert 125° 12′ into time.

Solution: $125° 12' \times 4 = 500\text{m. } 48\text{s.} = 8\text{h. } 20\text{m. } 48\text{s.} = \text{ans.}$

Example 2. Convert 110° 35′ 12″ into time.

Solution: $110° 35' 12'' \times 4 = 442\text{m. } 20\tfrac{48}{60}\text{s.} = 7\text{h. } 20\text{m. } 20\tfrac{48}{60}\text{s.}$

Note: When converting seconds of arc into time, it must be remembered that fractions are sixtieths. Thus, the value of 12″ is $\frac{48}{60}$ seconds. Likewise, the value of 57″ is $3\frac{48}{60}$ seconds (usually designated 3.8s).

22. To find the difference in time between two places, find the difference of longitude and convert this difference into time.

Example: What is the difference in time of a clock in London and one in New York City?

Note: New York City keeps clocks set to 75th meridian time. London keeps Greenwich time.

Solution: Longitude (time meridian) of N. Y. = 75° W.
Longitude " " " London = 0°
Difference in Long. of time meridians = 75° or 5h.

London time is therefore 5 hours ahead of New York.

23. From what has gone before, it is apparent that should each city keep correct time as indicated by the sun, hopeless confusion would result. Even within a given town or city, any travel to the east or west would necessitate a change of time. To overcome this, each country has adopted one or more *standard times,* depending on the size of the country.

24. The standard time for England is that of the Greenwich meridian. In other words, when it is noon on the meridian of Greenwich, it is noon all over England. In the United States, four standard time zones are adopted; eastern, or 75th meridian;

central, or 90th meridian; mountain, or 105th meridian and pacific, or 120th meridian.

Example: A plane makes a flight from New York to Los Angeles. Assuming that the pilot's watch was set correctly at New York, what would be its error when Los Angeles was reached?

Solution: Time meridian of N. Y.— 75° W.
" " " L. A.—120° W.
Difference of longitude — 45° or 3 hours.
The watch would be 3 hours fast = ans.

25. Figure 19 is a chart of the world on which the meridians are shown every 15°, or 1 hour apart. Referring to this chart, the time at San Francisco, California, when it is noon at Greenwich (San Francisco being about 120° west), would be 4 o'clock in the morning.

26. Any position on the earth's surface may be determined when its latitude and longitude are known.

Example: What is the position of point D on chart, figure 19?

Latitude 50° N.
Longitude 90° E. = ans.

Example: What is the position of point C, on chart figure 19?

Latitude 50° N.
Longitude 105° W. = ans.

Example: What is the latitude and longitude of point A′, figure 19?

Latitude 30° N.
Longitude 45° W. = ans.

Example: What is the position of point B′, figure 19?

Latitude 20° S.
Longitude 90° E. = ans.

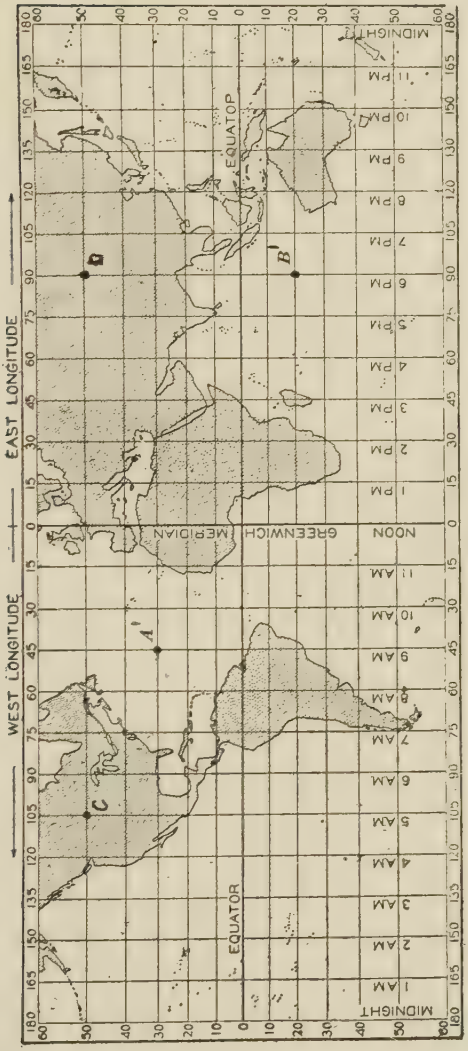

WEST LONGITUDE
EAST LONGITUDE
EQUATOR
EQUATOR
GREENWICH MERIDIAN
MIDNIGHT
NOON
MIDNIGHT
A
A'
B
B'
C
D

FIG. 19

CHAPTER III

CHARTS AND MAPS

1. A map, or a chart, is a representation of a part of the earth's surface on a flat sheet of paper, showing various particulars peculiar to the section shown. Since the form of the earth is globular, it is evident that any representation of its surface on a flat sheet of paper is necessarily an artificial construction. In order to understand and intelligently use maps and charts, it is necessary to know something about the manner of their construction and the peculiarities of those most often used.

2. In order to insure a true representation of any portion of the earth's surface on a flat piece of paper, there are certain conditions that must me fulfilled, namely: (1) conformity, (2) equidistance and (3) equivalence.

(1) *Conformity* requires a geometrical similarity between the original and the image; that is, angles on the map must be equal to angles on the earth's surface.

(2) *Equidistance* requires the distances from any two places to the center of the map or chart shall have the same ratio to each other as the corresponding distances on the earth.

(3) *Equivalence* requires areas on the map or chart to have the same ratio to each other as corresponding areas on the earth.

3. The only representation of the earth's surface that will fulfill all three of the above requirements is a globe. But, a globe is rather inconvenient for finding bearing, distances, plotting courses, etc. Therefore, when constructing a chart or map, one must be satisfied with the strict fulfillment of one of the above conditions and satisfy the others as near as possible. This is accom-

plished by applying different methods of construction. Among the methods most extensively used are the *Mercator* and *Polyconic* projections.

4. Without touching on the underlying mathematical principles involved, the characteristic features of the polyconic projection are as follows: the space to be represented is considered as having been peeled off the globe and divided by the latitude parallels

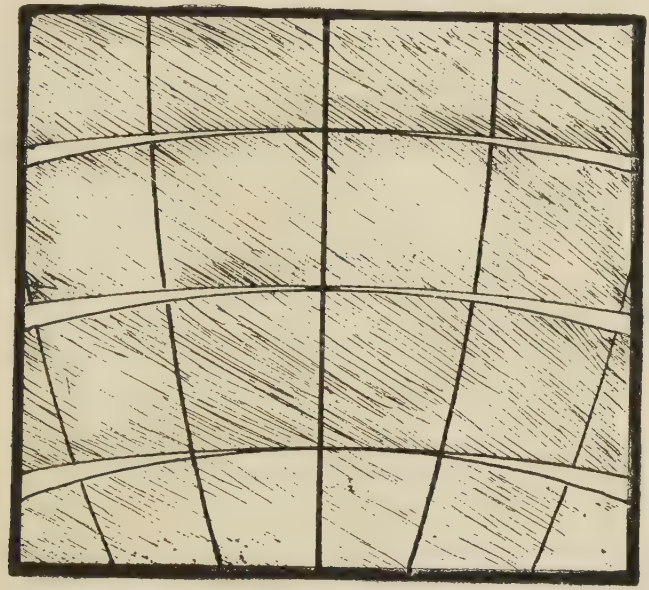


FIG. 20

into narrow strips. These strips are then placed so that the middle meridian of each constitutes the middle meridian for the entire sheet. It will be noticed that the zones touch each other only along the middle meridian and leave open spaces between their ends. See figure 20. In order to fill these open spaces and make the chart complete, the ends of each zone are stretched, so to speak, so that the lower edge of one zone will meet the upper edge of the next one. As a result of this stretching, the parts of the chart near the vertical edge are somewhat distorted. The

latitude parallels are not parallel with one another and, with the exception of the middle meridian, the meridians are curved lines converging toward the poles. On large scale charts, this curvature of the meridians is hardly noticeable, but, on charts embracing several degrees of latitude, it is quite apparent.

5. The center part of a Polyconic projection, in fact, the greater part of the chart, the exceptions being the parts near the vertical

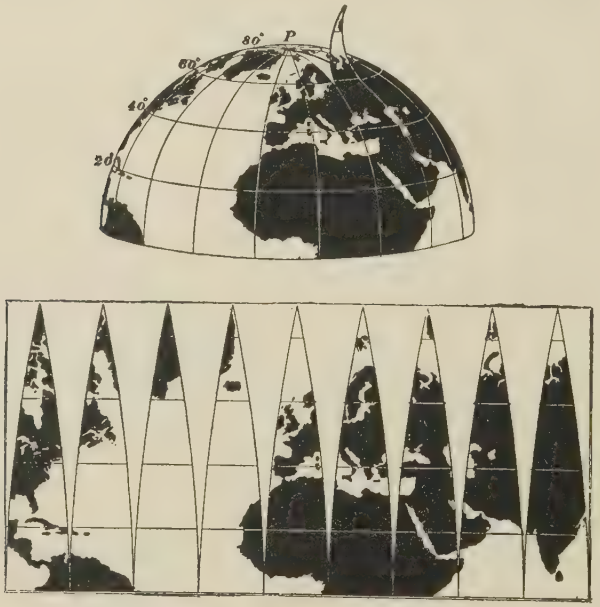


FIG. 21

edges, satisfies the conditions of conformity, equivalence and equidistance.

6. This projection has certain advantages for the representation territory running north and south, and, for this reason, is extensively used by the United States Coast and Geodetic Survey in the preparation of marine charts of the Atlantic and Pacific seaboards.

7. The course, or line of bearing, between two places on a Poly-

conic chart will necessarily be represented by a curved line if properly laid out. However, if the scale of the chart is large, the bearing may, without any practical error, be represented by a straight line, especially when the two places are situated near the center of the chart.

8. When the places are widely separated in longitude, and a straightedge is used to find the course between them, a plane following this line will, at the end, be nearer the elevated pole by a fraction that amounts to about 1½ miles for every hundred run. This error is somewhat more on charts of small construction.

9. A Mercator projection may be explained as not a projection, in the true sense of the word, but, the result of the following operation: by stripping off the globe the gores formed by the meridians and placing them in regular order beside one another on a flat surface. See figure 21. The upper surfaces are stretched laterally, so to speak, until the edges meet and fill in the vacant

FIG. 22

spaces. See figure 22. Now, in order to restore a balance of orientation, or the relative position and direction of spaces that are distorted horizontally, it is necessary to distort them in equal proportion vertically. See figure 22(a). On account of the distortion, areas and spaces in higher latitudes appear much larger in comparison with those of the equilateral parts than they really are.

10. By inspection, we find all meridians on a Mercator projection are parallel straight lines and the degrees of longitude all equidistant. The latitude parallels are everywhere at right angles to the meridians and hence the rumb line, or the track of a plane that steers a straight and continuous course, can be represented

FIG. 22A

as a straight line. For navigational purposes therefore, the Mercator has decided advantages over the Polyconic projection.

11. Further investigation of a Mercator projection shows that the degrees of latitude are all unequal, being increased in length from the equator toward the pole. These augmented latitudes, expressed in minutes of the equator, are called meridional parts and the meridional part for any latitude, expressed in minutes of the equator, is the actual increased distance, or stretching of that latitude. For example, the true distance from the equator to the 25th parallel is $25 \times 60 = 1500'$ or 1500 nautical miles. On a Mercator projection this distance, measured in minutes of the equator, would be 1540.3′, and is known as the meridional part of latitude 20°.

12. Tables of meridional parts have been constructed which show the length in minutes of the equator into which the true latitudes must be expanded when constructing a chart on the Mercator projection.

13. Generally speaking, maps are a representation showing areas of land and are usually on the Polyconic projection, while charts are representations showing areas of water and are usually on the Mercator projection.

14. There are two general types of maps in common use, those stressing the physical characteristics, that is, showing height of the ground, or mountain ranges, watersheds, etc., and those showing geographical data such as towns, railroads, lakes, etc. The first type is used only in connection with the second as they are usually of very small scale and show only the physical character of the country. The second type usually gives very little information regarding the height of land and, therefore, when planning a long flight over unknown country, both types should be used. For example, a pilot planning a flight through the Republic of Mexico would want a physical map to show him the altitudes he might expect on the various parts of his journey and to assist in planning the route over the best country from one place to another, while a good geographical map would be needed to plot the courses and measure the distance.

15. In the purchase of maps, the pilot will of course be governed by what is available. In all the larger cities, stores dealing exclusively in maps and charts will be found. Such stores usually offer a wide and varied assortment such as railroad location maps, state highway, post office location, waterways, etc., each type having been compiled for a special purpose. If possible, Department of Commerce strip maps, made for aviation purposes, should be used. They show all essential data and landmarks visible from the air, including landing fields, and have magnetic courses and

distances plotted. If strip maps are not available, any good map with a scale of from 10 to 20 miles to the inch will serve. Automobile road maps and maps of similar scale are of little use as they are of so small a scale they generally show a confused mass of small details, quite satisfactory to a man reading signs on the ground, but confusing to one several thousand feet in the air.

16. The Rand McNally Company publish what is known as a *Standard State map*. The scale averages about 1 inch to 10 miles, being slightly different for each state, and all cities, towns, railroads, electric roads, rivers, lakes, etc., are accurately shown. They are furnished in a heavy paper folder, one sheet to a state. In the near future, the Standard State maps will be published showing aeronautical data and will be known as *Rand McNally State Air Trails*. The borders of Air Trail maps are divided, in addition to latitude and longitude graduations, into 10 mile intervals by red triangles. A large triangle is placed every 50 miles to facilitate measurements. All airports and landing fields are prominently marked. Established airways are shown by solid red lines, small figures indicating their magnetic direction. Lighted beacons, radio marker beacons, compass stations, etc., are plainly shown, together with the local variation. Each map is accompanied by a booklet which lists all airports shown on the map, giving the distance and direction from the city and the size, class and operator of each. Air Trails are undoubtedly the best general maps available for aviation purposes and compare quite favorably with Department of Commerce strip maps.

17. If strip maps or Air Trail maps are not available, postoffice location maps may be used to advantage. They show all cities, and towns having a postoffice, connecting highways and all railroads. No topographical data is shown and only the principal waterways and lakes. They are furnished one state to a sheet on an average scale of 1 inch to 10 miles. The elimination of

township lines, county lines and topographical data make these maps easy to read, hence, they are preferred by many pilots for work in open country.

18. Generally speaking, special purpose maps should be avoided as they feature some particular thing to the exclusion of detail essential to the flyer and are generally of very poor scale. An exception may be noted where a general map covering several states is desired. Such a map, however, is used only in planning the route to be followed and not for actual navigation. A railroad location map of the entire country is ideal for this work as all the cities, railroads, state lines and principal bodies of water are shown, and the relative location of the various parts of the country may be seen at a glance. However, the scale and lack of essential detail make this map of little value for actual navigation.

19. Maps on which the physical characteristics of the country are stressed are known as *Topographical maps.* Altitudes are referred to some known point called the *Datum level,* and show the height above this level. Except for maps of a purely local or special character, heights are expressed in feet above sea level. A color column is sometimes shown at the side, and heights on the map are indicated by different coloring, the darkest portions representing the highest points. On the better grade of maps, *contour lines,* connecting all places of equal altitude, are also shown, forming irregular curved lines all over the surface. A certain fixed height, known as the *vertical interval,* is the distance between the contour lines and the value is sometimes given in the footnotes. Knowing the vertical interval, a careful study of the map will give an excellent mental picture of the country. Good topographical maps of an entire country may be obtained on a scale of approximately 1 inch to 50 miles.

20. When operating along the coast, marine charts may some-

times be used to advantage. They show numerous lighthouses, lightships and other navigation aids with individual characteristics. On many parts of the coast, large powerful lighthouses overlap each other, and it is a simple matter to run from one to the next.

USE OF MAPS AND CHARTS

21. When a map or chart is properly spread out, the top is the north, bottom the south, right side east and left side west. On a polyconic projection, the scale for measuring distance is inserted at a suitable place, either near the borders or in one of the lower corners. There are usually two scales, one for statute and one for nautical miles. On a Mercator projection, the graduated meridian at the right and left side of the chart is used for measuring distance. On all maps and charts fit for navigation, the latitude scale is shown on the right and left margin, while the longitude scale is shown on the top and bottom margin.

22. The principal instruments used in chart work are the *Protractor, dividers* and *parallel ruler*. See figure 23. There are a number of other so-called instruments offered to navigators from time to time, under various names, such as *course correctors, distance finders, bearing indicators,* etc. In most instances, they are of little if any practical value and will not be considered here.

23. To find the course between two places shown on the map or chart, connect them with a light pencil line using any straightedge of sufficient length. This line is known as the *course line, line of bearing,* or a *track*. Place the center mark of the protractor on the point of intersection between the course line and the meridian. The required course or bearing is now measured with the protractor.

24. The Pioneer Instrument Company recently brought out a very handy protractor which is especially useful when in the air.

It is made of transparent celluloid having black graduations, making for easy reading, and the entire circle, representing 360° of the horizon, is shown instead of 180° as is customary. From the exact center, a long black string is attached to facilitate rapid measurements. In using this instrument, the center is placed over the point of departure and the protractor is carefully turned until

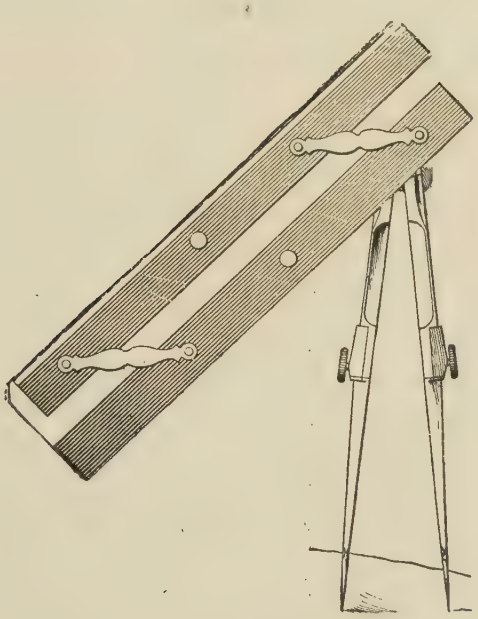


FIG. 23

its 0°-180° line parallels the meridians. The string is now stretched to the point of destination and the course read from the graduated arc.

25. On marine charts, a *compass diagram* or *rose* is printed on the face of the chart. The compass rose consists of two circles, one inside the other, representing the horizon. The outer circle is graduated into 360°, the 0°-180° line being parallel to the meridians. The inside circle represents magnetic directions and will be explained later. To find the course or bearing from the

compass rose, the parallel ruler is used. This consists of two rulers connected by crosspieces of metal, working on pivots in such a way that they may be spread apart or pushed together and still remain parallel to each other. To find the course or bearing between two points shown on the chart, they are connected with a light pencil line as already explained. One edge of the closed parallel ruler is now placed along the course line and held firmly, while the ruler is pushed open until the other edge cuts the center of the nearest compass rose and the bearing read off. It may be necessary to take several steps with the ruler to reach the rose, but the operation is so easy as to require no further explanation. The one point to be careful of is to maintain the parallelism of the line during the several steps. It is well to measure each line at least twice. If desired, the protractor may be used as already explained instead of the parallel ruler.

26. If a compass course is to be found from the course or bearing obtained from the map, various corrections must be applied. The operation of correcting these courses will be fully treated in *Correction of Courses.*

27. To measure the distance between any two places shown on the map; if the two points lie on the same meridian, or very close to it, measure with the dividers the difference of latitude in minutes. This will be the required distance in arc, or nautical miles, since one minute of latitude is equal to one nautical mile. If statute miles be desired, multiply the distance by 1.151.

28. If the two places are not on the same meridian, and the map be on the polyconic projection, connect them with a light pencil line and, then, using a pair of dividers, step off the distance according to the measuring scale.

29. If the two places are not on the same meridian, and the map be on the Mercator projection, connect them with a light pencil line, and then, if the distance be short, use the dividers to

measure it on the graduated meridian, as nearly opposite the two points as possible. If the distance be great, find the latitude of the approximate center of the line. This is known as the *middle latitude*. From the graduated meridian at the side, and near the middle latitude, take a distance of 5, 10, or 20 miles with the dividers and step off the length of the line. Thus, if the unit selected be 20 minutes of the graduated meridian, and the line requires 20 steps of the dividers, the distance will be $20 \times 20 = 400$ nautical miles.

30. On a Mercator projection of large scale, a measuring scale is sometimes given, in which case it will of course be used. Usually, however, due to the construction of this type of map or chart, a measuring scale that is correct for one section of the chart would be in error when used in another section much removed in latitude. It may be well, at this time, to review the section above describing the construction of a Mercator chart.

31. To find the latitude and longitude of a place, (1) use the dividers to find the distance to the nearest parallel and, by following this parallel to the graduated meridian at the side of the chart, the distance from it may be laid off and the latitude read directly. (2) Use the dividers to measure the distance to the nearest meridian and follow this meridian to the top or bottom of the map, where the longitude may be read directly.

32. When using a polyconic projection, the straight line connecting the point of departure and point of destination is really a curve, and *does not intersect all meridians at the same angle.* If the course be measured from a meridian near the point of departure, it will be in error to the extent of about 1½ miles in 100 miles run in latitudes between 45° to 50°. This may be more readily understood if a straightedge be placed tangent to a parallel of latitude and the curvature of the parallel noted. Thus, a pilot making a long flight from the City of Boston to the west-

ward would, if it were possible to steer a perfect course, find himself working gradually to the north of his line.

33. In a flight of two or three hundred miles, the error is not worthy of consideration and may be disregarded. The course should, however, be measured on a meridian about half-way between the two points, thus minimizing the error. In a long cross-country trip, the course line cannot be considered as a straight line. For example, a line from New York City to Denver, Colorado, would, on a polyconic projection, show an appreciable curvature, and the course as measured at New York and the course as measured at Denver would differ by several degrees.

34. The remedy for this is to make a long trip in legs or sections. For example, in making the trip from New York to Denver, plot the course line in the usual manner. Then, divide it into sections of about 200 miles each and measure the course for each leg. In this way a slight change of course will be made to the left every two hundred miles and the line on the map followed without difficulty. The same thing would be done on a non-stop flight from Denver to New York but, in this case, the course would be altered slightly to the right instead of the left.

35. On a Mercator projection this wrinkle is not present as all meridians and parallels are straight lines, parallel to each other, and the course line will intersect all meridians at the same angle. Consequently, the course measured at New York and the course measured at Denver would be exactly the same. However, the distance by Mercator would be slightly longer, as the polyconic course is somewhat of a compromise *great circle.*

GREAT CIRCLE SAILINGS

36. We learn in geometry that the shortest distance between two points is a straight line that joins them. This is true on the

earth's surface but, the earth being a globe, a straight line joining two places on the surface must necessarily pass through some portion of the earth, while flying is confined to the air above. Therefore, the question is limited to the shortest distance between two places on and over the surface of the earth. This distance on a globe representing the earth may be found by stretching a thread from one place to another on its surface. Such a thread, extended around the entire globe, would be a great circle. The arc between the two places is known as the *great circle track*.

37. The principal reason for following the great circle route is the saving of distance and, consequently, time. Reduction of distance is greatest in high latitudes, between places much separated in longitude but in about the same latitude. It is least between places located nearly on the same meridian, as meridians themselves are great circles. For example, the distance by Mercator from San Francisco to Tokyo is 4,718 nautical miles, while the distance by great circle is 4,448 nautical miles, a saving of 270 nautical miles by following the great circle passing through both places.

38. The saving in distance can only be estimated after having laid out the great circle route on the chart and considered whether the regions through which it passes are favorable for flying. If, for any reason, the great circle route is not advisable, a route should be followed that will approach the great circle as near as is possible.

39. If, when making a long flight, the plane could be kept exactly on the great circle track, her head would always be pointed toward the point of destination. However, this would necessitate a continual though gradual change of course unless the track ran along a meridian or along the equator. In order to avoid this constant change of course, it is customary to consider a small arc of the great circle as a straight line. Points are taken on the

great circle track at convenient intervals and the course between each point and the next is noted on the chart. The plane then flies from point to point. Thus, in figure 24, if a plane flies from A to B along the great circle Acc′ c″ B, her first course would be from A to c, the second from c to c′, the third from c′ to c″

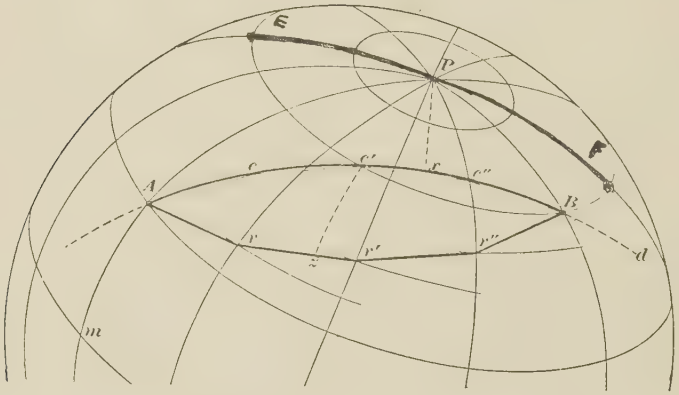


Fig. 24

X Is the Vertex. ZC′ Is the Point of Maximum Separation. Note the Saving of Distance Were It Possible to Fly from E to F Via the Great Circle

and so on. In this manner, advantage may be taken of the great circle track without frequent changes of course.

40. From an inspection of figure 24, it is evident a plane flying on the great circle track makes straight for the point of destination, and the track intersects the meridians at a constantly varying angle. On the other hand, the rumb track crosses all meridians at the same angle and the plane steers the same true course, but, she never heads directly at the point of destination until it is in sight.

41. From what has gone before, it is apparent that on either a Mercator or polyconic projection the great circle track must necessarily be represented by a curve, and this curve must lie in

a higher latitude than the rumb track. Thus, a great circle track in the northern hemisphere lies nearer the north pole than the rumb track, and in the southern hemisphere, nearer the south pole.

42. Figure 25 represents a great circle and a rumb track between point A and point B. The difference of longitude is the same for

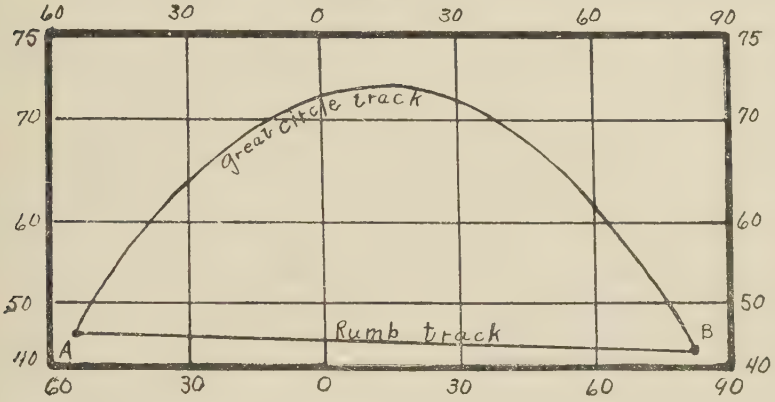


FIG. 25

both tracks, but the great circle track lies in a higher latitude and has the advantage of *shorter degrees of longitude,* and, consequently, is a shorter distance. The higher the latitude the more the track differs, which is especially true if the two points lie on the same latitude parallel.

GREAT CIRCLE DEFINITIONS

43. When following the great circle track, the first course steered is called the *initial course,* and the last one, the *final course.* If the point of departure and point of destination are on the same latitude parallel, the initial and final course will be the same.

44. The point on the great circle track that approaches nearest

to the pole runs perpendicular to the meridian and is known as the *vertex*. The vertex may or may not be situated *between* the two points, but if they are in the same latitude, it lies midway between them.

45. When the point of departure and point of destination are situated in the same hemisphere, a plane following the great circle will always be in a higher latitude than if the rumb track were followed. The point at which the great circle is at the greatest distance from the rumb track is known as the point of *maximum separation*. When the two places are located in different hemispheres, there must be two points of maximum separation—one to the northward of the rumb track in the northern hemisphere, and one to the southward in the southern hemisphere. The rumb track and great circle coincide at the equator.

TO FIND THE GREAT CIRCLE TRACK

46. Problems in great circle work may be solved either by spherical trigonometry or by graphic methods. The method of finding the track by calculation is a tedious one and of no practical value to the aviator, hence it will not be treated here.

47. Charts constructed on the *gnomonic* projection are called great circle charts and on such charts the great circle between any two points is a *straight line* connecting them. Thus, in figure 26, the straight line between A and B is the arc of the great circle passing through both points. The difference of longitude on such a chart is the angle at the pole P included between the meridians passing through the places. The chart represented in figure 26 is constructed for use between 40° and 70° latitude. As previously stated, the main advantage of the gnomonic chart is that the great circle track between two places may be represented by a straight line. Thus, the line AB is the great circle

track between the points A and B. The latitude and longitude of any number of points may be determined and the track thus tansferred to the regular chart or map where the courses and distances may readily be found by the usual methods.

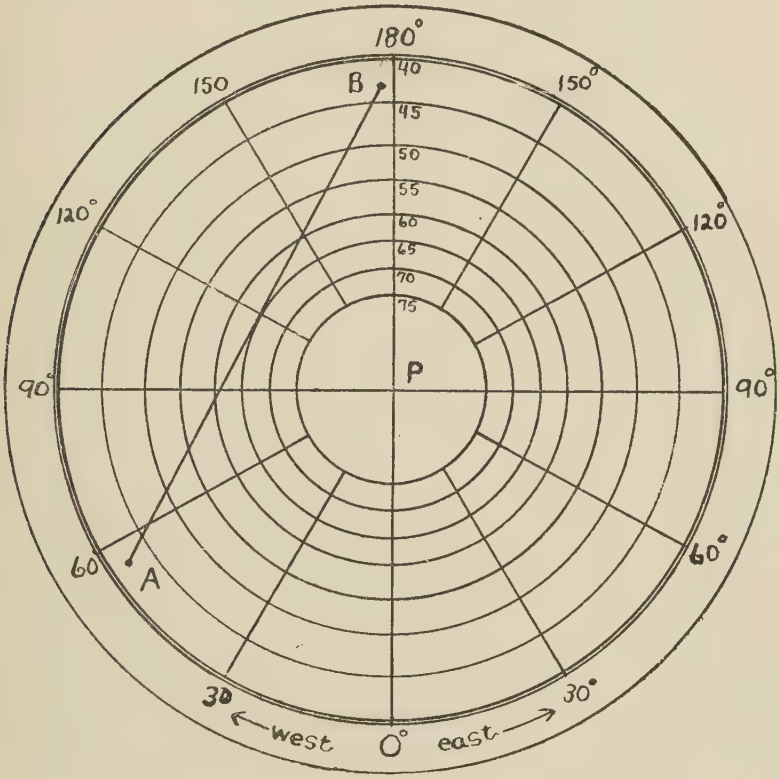


FIG. 26

48. On the simple form of gnomonic chart shown in figure 26, courses and distances along the great circle track cannot be found directly. The United States Hydrographic Office publishes a great circle chart for the use of mariners on which courses and distances are conveniently found by means of diagrams shown on the face of the chart. Full information for its use is given

on the face of the chart and therefore will not be given here. They may be obtained at any branch Hydrographic office.

49. The great circle chart, though accurate in high latitudes, gives a very distorted representation in low latitudes. In such parts of the world, however, the advantages of following the great circle are insignificant.

CHAPTER IV

THE COMPASS

1. The phenomenon displayed by a magnet of attracting small pieces of iron, steel, metal filings, etc., is known as *magnetism.*

2. Magnets are of two kinds, *natural* and *artificial.* A natural magnet is an ore called *lodestone,* which possesses the property of magnetism. The chemical composition of lodestone is about 72 parts iron and 28 parts oxygen. When an iron bar or needle is rubbed with lodestone, it becomes magnetized. Such bars or needles are known as *artificial magnets.*

3. If a bar magnet be plunged into iron or steel filings and then withdrawn, the magnetism of the bar will cause it to become covered with the filings, but not uniformly so. Around the ends they will arrange themselves in feathery tufts or balls which grow smaller toward the middle leaving that portion bare. See figure 27. The points around which the filings concentrate, that is the ends of the bar, are known as the *poles* of the magnet, while that section near the center, which is bare, is known as the *neutral zone.* An imaginary line connecting the two poles is known as the *magnetic axis.*

4. If a magnetized needle be suspended by a thread at its center of gravity, it will, after swinging back and forth for a time, come to rest in a certain definite direction pointing toward north and south. This tendency of the needle to lay itself in a north and south direction is called *polarity,* and is present in all magnets. The end of the needle pointing north is called the *north-seeking* or red pole, and the end pointing south is called the *south-seeking*

or blue pole. See figure 28. The north-seeking end of a magnet is said to have *red polarity*, while the south-seeking end has *blue polarity*. The ends of magnets are stamped N. or S. and sometimes painted red and blue respectively to show the polarity.

5. When two magnets, or magnetized needles, are placed near each other, the north-seeking end, or red pole, of one magnet will

Fig. 27

Fig. 28

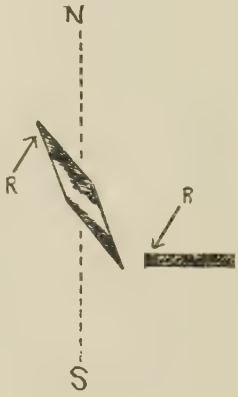


Fig. 29

repel the north-seeking or red pole of the other, while it will attract the south-seeking or blue pole. In other words, poles of a like name repel each other, while poles of contrary name attract each other. This phenomenon is known as the *law of magnetic attraction and repulsion*. See figure 29.

6. The fact that a magnet, balanced at its center of gravity, will take up a definite north-and-south direction has led to the theory that the earth itself is a huge magnet having a blue pole in the vicinity of the geographical north pole which attracts the red end of the magnet, and a red pole in the vicinity of the geographical south pole which attracts the blue end.

7. Due to the fact that the geographical and magnetic poles of the earth do not coincide, the direction indicated by the magnetic needle suspended at its center of gravity will generally differ somewhat from the true direction. The needle indicates the magnetic north-and-south line which is technically known as the *magnetic meridian*. The angle between the *true meridian*, or true north-and-south line, and the magnetic meridian is known as *variation* or *declination* of the needle. See figure 30.

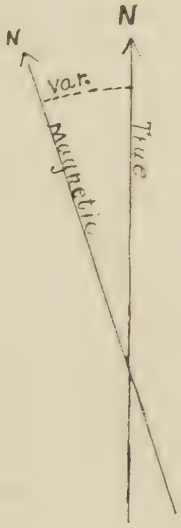


FIG. 30

8. The *compass* is an instrument in which the properties of a magnetic needle are utilized to indicate direction. In its simple form, it consists of a needle attached to the under side of a very light circular card, the circumference of which is divided into degrees. This card is fitted in its center with a conical socket called the *cap* and is delicately balanced on a central pivot around which it is free to move in the horizontal plane. By this arrangement the card will partake of the motion of the magnetic needle and maintain a position in accordance with its magnetic force.

On the inside of the compass bowl is a narrow vertical line known as the *lubber line.* This line, when the compass is properly mounted, will show the direction in which the plane is heading. Usually there are two lubber lines diametrically opposite each other. When the compass has been placed in position these lines should be exactly parallel with the ship's fore-and-aft line.

9. To head the plane in any desired direction, the rudder is moved slightly until the ship begins to swing. The lubber line, being secured to the bowl, will swing with the ship while the card will remain stationary by virtue of the attached magnetic needles. The ship continues to swing until the lubber line and desired graduation on the compass card coincide, when it is steadied by use of the rudder. Any variation from the desired direction will be instantly shown by the lubber line moving to right or left of the desired heading.

10. The compass usually found in an airplane is either of the vertical or flat top type with either a float or non-float card. As the principal of all magnetic compasses are the same, the following general description will serve for all. See figure 31.

11. Two or more highly magnetized needles are secured to the underneath side of a circular card. The side of the card holding the red or north-seeking ends of the needles is marked north, or 0°, while the side holding the blue or south-seeking ends is marked south, or 180°. Additional graduations are then placed on the edge of the card at equidistant points, their number depending on the size of the card and the accuracy of the finished instrument. In the *float type* card, a bottom is fitted making it an air-tight float which will support most of the weight of the card and needles. Most modern cards are of the non-float type, consisting of a sheet of very light metal, or celluloid, with the edges turned down much like a saucer face down. Around the edge of the card are *reverse graduations,* and by looking at that

FIG. 31

part of the vertical edge which is aft, the direction of the plane's head may be read off direct. Flat top instruments show direct graduations on top and reverse graduations on the side, while vertical instruments (in which the top is not visible) have only reverse graduations. In the exact center of the card is a jewel bearing on which the card is balanced.

12. The bowl consists of a globular or cylindrical shaped metal or glass container, fitted with arms for mounting on the instrument board or fuselage, and is filled with alcohol and water, or, in the case of a celluloid card, kerosene, to dampen the oscellations of the card. In the bottom of the bowl is fitted a metal pedestal on the point of which the jewel bearing of the card rests. On the after face or covering lense is the lubber line. A second lubber line will be found in the flat top compass, near the forward edge of the card, for direct readings. All modern aerial compasses are fitted with a compensating unit, built in the frame, thus eliminating the use of loose magnets for compensation.

13. The graduations found on the compass card start at 0° and run clockwise to 360°. Each degree is not marked, however. On the older cards it was customary to place a graduation and mark every 30°. Thus, from north to south, they ran N., 3, 6, E., 12, 15, and S. Graduations of this kind are said to be in units of 10; 3 being 30°, 12 being 120°, 15 being 150°, etc. Modern cards usually have a mark every 5° with figures every 30°. The figures, as in the case of older cards, are in units of 10°. Thus, if course 310° is desired, the lubber line would be held on the second mark from 30, between 30 and 33. Again, if the course be 285°, the lubber line would be held on the third mark from 27, between 27 and 30. If the course be 15°, the lubber line would be held on the third mark from 0, between 0 and 3.

14. The pilot will meet with different graduations from time to time and should make sure he knows how the card is marked

before attempting to steer a course. With the flat top instrument no confusion should result from the reversed readings, as one may always refer to the top and front lubber line and see the course direct, but care must be exercised when using the vertical type where reverse readings only are shown. Bear in mind that reverse bearings show the course being steered when looking from aft forward.

15. Recent development in instrument making has brought out a very accurate and especially useful aerial navigational accessory in the *earth inductor compass*. Briefly described, the instrument consists of three major units; a generator, a controller and an indicator. A flexible shaft connects the generator and the controller. An electric cable connects the generator and the indicator. See figure 32.

16. The generator is the direction-responsive element of the inductor compass. It is the same in principle as any electric generator except that it has no artificially induced field. It has an armature, a commutator and a pair of brushes. The armature unit is supported on gimbols so that its position will be undisturbed by ordinary rolling and pitching of the plane. A windmill drives the armature and commutator through a universal joint. The brushes are supported for orientation about a normally vertical axis and electrical connections are made to them.

17. The indicator is a galvanometer which is electrically connected by means of the cable to the brushes of the generator.

18. The controller is purely a mechanical device connected to the generator by a flexible shaft. Rotation of the controller causes a corresponding rotation of the brushes of the generator. Dials on the face of the controller show the angle through which the brushes have been moved in relation to the plane's fore-and-aft line.

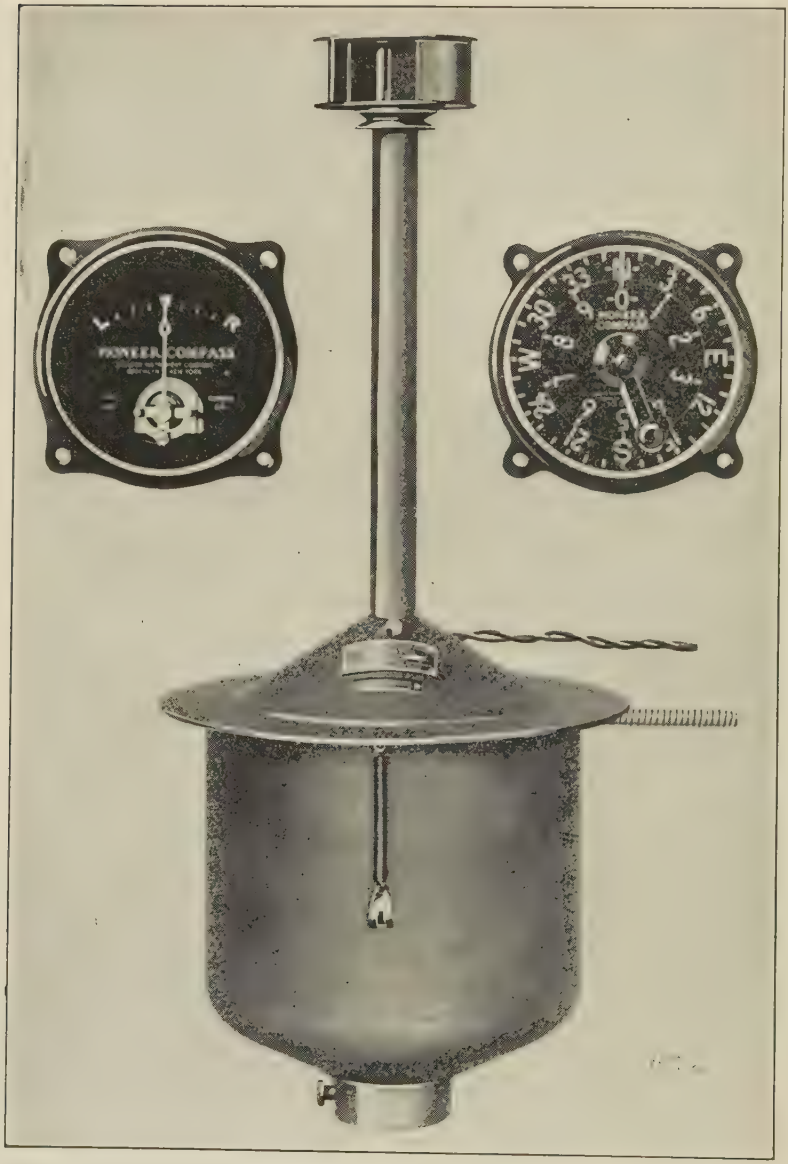


FIG. 32

19. The operation of the compass depends upon the rotation of the armature of the generator which cuts lines of flux of the earth's field and generates electricity. When the brushes of the generator are in the plane of the magnetic meridian, that is, when they are magnetic north and south, the output of the generator is maximum, and, minimum (zero) when the brushes are east and west.

20. From what has been said above, it will be understood that should a plane be steering west magnetic, and the controller set on 270° as the course, the brushes of the generator will be parallel to the plane's fore-and-aft line, or, in an east and west direction. With brushes in this position there is no electricity being generated and the indicator will show zero. As long as the plane is kept headed exactly magnetic west, the indicator will remain on zero and the pilot will know he is on the exact course. Now, suppose the pilot gets off his course somewhat, say to the northward. The brushes of the generator moving with the ship are

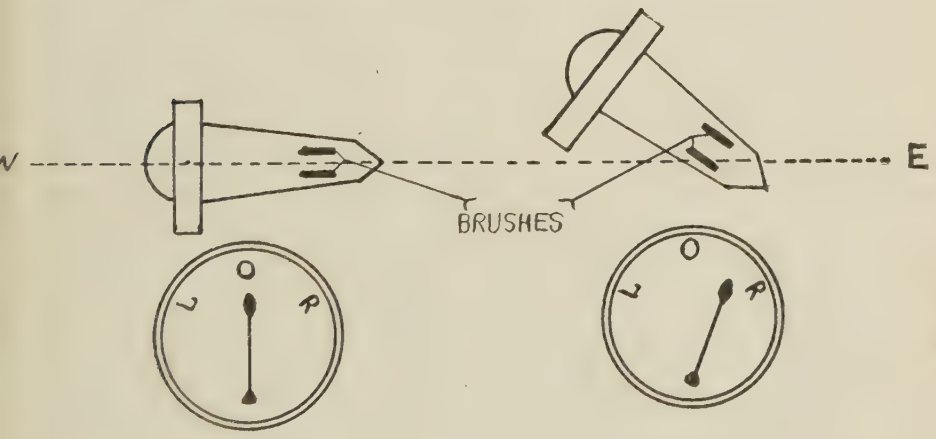


FIG. 33

no longer east and west and the generator begins to put out electricity, which registers on the indicator, slowly at first but in-

creasing in amount as the plane gets farther off her course, and the brushes get farther from the east and west line. When the pilot again looks at the indicator, he will see the hand, instead of being in the center has moved to the right, the amount depending on how far off the course he may be. He then brings the ship's head to the left until the indicator hand is again on zero. The brushes are now magnetic east and west, there is no electricity being generated and the plane is again on its course. See figure 33.

21. All courses are set by the controller which is graduated in degrees, clockwise from 0° to 360°. There is an outer and inner dial, the former showing tens of degrees and the latter single degrees. In setting the course magnetic west (270°), turn the controller crank until 27 on the outer dial and 0 on the inner dial are directly on the lubbers line. Now, when the plane is flying magnetic west, the indicator will show zero, as the generator brushes are magnetic east and west. Any deviation from this course will cause an output of electricity which will register on the indicator, showing the plane is off the course, approximately how far, and which way.

22. It is now desired to change course to, say 293°. Turn the controller crank until 29 on the outer dial is just past and 3 on the inner dial is exactly on the lubbers line. Turning the crank revolves the brushes and the generator immediately begins to put out electricity, which registers on the indicator, and will continue to do so until the brushes are again in an east and west direction. In changing the course 23° to the right, the brushes were moved a like amount off the east and west line *to the left*. Now, as the plane swings to the new course, the brushes are gradually brought back into the east and west position until, when heading 293°, the brushes are east and west, the generating of electricity stops and the indicator shows zero.

23. All courses are set on the controller as explained above. For a course of 15°, set 1 on the outer dial a little past, and 5 on the inner dial exactly on the lubbers point. The indicator will then show zero, as long as the plane is on the course, and the indicator hand will move to the right or left when the ship deviates to the right or left of the course. For a course of 87°, set 8 on the outer dial a little past, and 7 on the inner dial exactly on the lubbers line. For a course of 344°, set 34 on outer dial a little past, and 4 on the inner dial exactly on the lubbers point.

24. There is one important point to be remembered when using an inductor compass. The indicator shows zero when exactly on the course, but should the plane be headed on the reverse course, the indicator will also show zero. For example, suppose a plane flying west (270°) begins to turn to the north. As the ship swings away toward the north, the angle of the brushes to the east and west line increases and electricity generated begins to register on the indicator, increasing in amount until north is reached, when the brushes will be north and south, causing the generator to put out at a maximum. The indicator hand will now be at the extreme right of the indicator dial. Now, suppose the turn is continued to the eastward. As the brushes pass the north and south point they begin a return to the east and west direction and the generator output falls off gradually until, when reaching east, it becomes zero. As stated above, when on the north point, the indicator hand will be at the extreme right of the indicator dial, showing the plane is off the course to the right. As the ship nears east, and the electric current is proportionately reduced, the indicator hand will move back toward zero, but, it is still on the *right of the dial,* indicating the plane is to the *right of the course.* When the plane finally heads east, the indicator will show zero but you are now 180 degrees off the proper course.

25. The running of the reverse course is easily avoided however,

by watching the indicator hand. The indicator hand and the plane must move in the same direction. For example, if the plane is headed to the right, the hand moves to the right, and vice versa. If, when swinging right, the indicator hand moves left, the plane is running the reverse course and must come about 180°.

26. The earth inductor compass, if properly installed, requires but slight attention. However, every 50 hours' service, the entire installation should be gone over and carefully oiled. A maintenance chart and instructions are furnished with the instrument.

SUN COMPASS

27. When flying in the Arctic or Antarctic regions, due to the proximity of the magnetic poles, magnetic disturbances render the ordinary compass difficult to manage, and navigators must resort to constant astronomical observations to steer the desired course. When the sun is visible, its true bearing (azimuth) may be readily calculated. Knowing the sun's azimuth, it is only necessary to head the plane the proper angle to the right or left in order to make good the desired course. For example, the bearing of the sun being 135°, a plane desiring to fly 90° would head 45° left of the sun.

28. The *sun compass* consists of a series of prisms so arranged that a reflection of the sun is thrown on screen in front of the pilot when the plane is on the desired course. This is done by means of a reflecting prism which may be revolved around its horizontal axis and set for the azimuth of the sun. A vertical line on the screen serves as a lubber line and deviations from the desired course are shown by the reflected image either side of the line.

29. As the sun is constantly changing in azimuth, the reflecting prism is fitted with a clock-like mechanism which turns it in the

horizontal plane at a speed equal to that of the sun. Thus, when once set, the compass automatically reflects an image on the screen in front of the pilot as long as he is on the correct course.

COMPASS—CARE AND INSTALLATION

30. Probably the first consideration in mounting a compass is location. It must be visible to the pilot at all times and, therefore, should be in front of him and about in his normal line of sight. This is easily done in most open ships, where the ideal location is on the fuselage outside the windshield. On a cabin plane, the locating situation is quite different. Generally speaking, the engine cowling, as close as possible to the windshield, offers the best position, though here it will be influenced by the engine and electrical equipment to a certain extent. The instrument board is not only out of the normal line of sight, but a compass mounted thereon is subject to unusually severe vibrations. Optical systems for reading a distantly located compass have been used successfully in some ships; the instrument being mounted some distance in back of the pilot and a looking glass mounted on the windshield. In extreme cases, a compromise location must be selected, as far as possible from any magnetic influence, where it may be quickly and accurately read. It should be on the center line of the ship if possible.

31. Having selected a location, the instrument should be firmly secured in position, using great care to have the lubber line parallel to the fore-and-aft line of the plane. In some locations it may be necessary to reinforce the surface upon which the compass is to be mounted. For example, when the cowling is used, a light wood stiffener should be placed inside. This will materially lessen vibrations.

32. With the earth inductor compass, the problem of location is greatly simplified. This being a remote reading instrument, it is only necessary to place the generator where the magnetic disturbance is minimum. The indicator is of course placed on the instrument board.

33. A properly located well secured compass will give excellent service indefinitely. However, it is a delicate instrument and should be treated as such. When extensive repairs are contemplated, which would subject the compass to severe jarring or vibration, it should be dismounted and carefully stored out of harm's way. Incidentally, it should be set upright in some safe place and not thrown carelessly into a tool kit to be bumped around until wanted.

34. Bubbles will appear occasionally and should be removed at once. This may be easily and quickly accomplished by taking the compass from mounting bracket and, with the filling hole up and plug out, manipulate the instrument until the bubble comes under filling hole. Using a medicine dropper, fill the hole with kerosene until it overflows. Replace the plug and set up tightly.

35. Sometimes a compass will become disabled in some way, such as a cracked and leaky lense, or a warped card. Such an instrument should be dismounted at once and returned to the maker for repairs. Continued service will invariably ruin a faulty compass that could probably have been repaired quite reasonably.

CHAPTER V

COMPASS ERRORS

1. The compass is affected by three errors known respectively as *variation, deviation* and *local attraction.* Variation is caused by the magnetism of the earth; deviation by the magnetism of the iron and steel used in the construction of the plane itself; and local attraction, by some temporary magnetic influence close to the compass.

VARIATION

2. The direction assumed by a magnetic needle when suspended at its center of gravity, free to swing in the horizontal plane, and

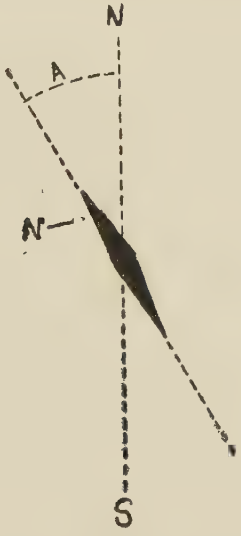


FIG. 34

influenced only by the attraction of the earth, is known as the *magnetic meridian* of that place.

3. The angle that the magnetic meridian makes with the true meridian, or, what is the same, the angle that the direction of a suspended magnetic needle makes with the true north and south, is called the *variation* or *declination* of the magnetic needle in that locality. Thus, in figure 34, if NS represents the true, or geographical meridian and N the north-seeking end of a suspended magnetic needle, the angle A, formed by the needle and the meridian is the variation of the compass.

4. Variation is named easterly or westerly, according to the direction in which *the north point of the needle is deflected from*

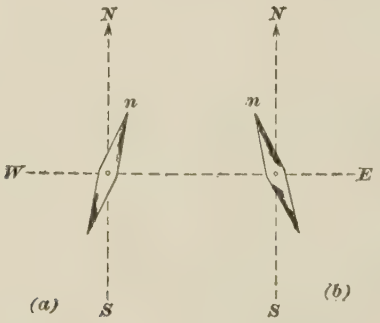


FIG. 35A FIG. 35B

the true meridian. Thus, if the north point is deflected to the east of the true meridian (fig. 35a) variation is easterly; if deflected west (fig. 35b), the variation is westerly.

5. The variation of the compass is different at different places on the earth's surface and undergoes a gradual change from year to year. Where the magnetic meridian and true meridian coincide, the variation is zero. Lines on charts and maps connecting these places are known as *lines of no variation,* or *agonic lines.*

6. In figure 36, which represents a map of the world, heavy black lines indicate the lines of no variation, westerly variation by fine lines, and easterly variation by dotted lines. A study of this map will show the variation to be westerly over the eastern part

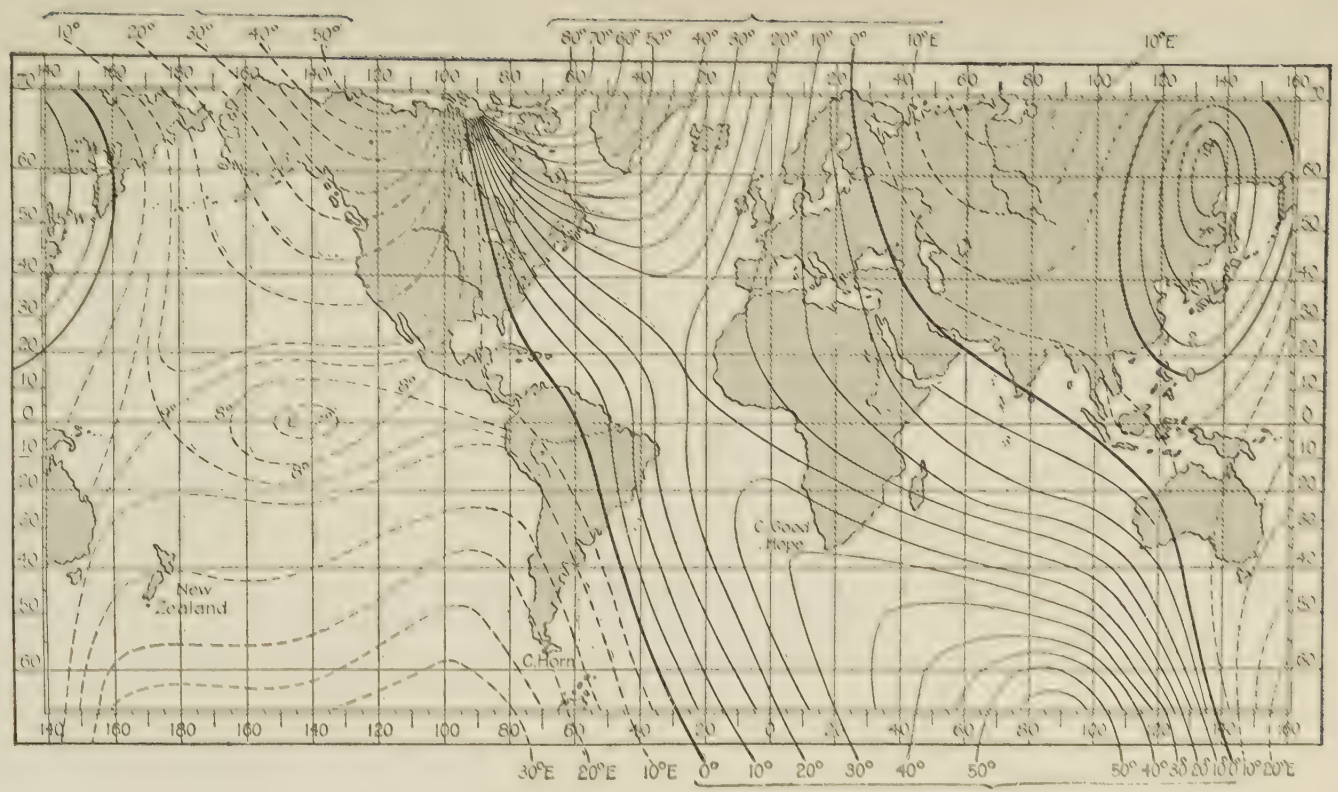


FIG. 36

of the United States and the Atlantic Ocean and easterly over the western part and over the Pacific. The lines connecting places on the earth's surface where the amount of variation is equal are called *Isagonic lines,* and charts showing such lines are called *Isagonic charts.*

7. The study of the earth's magnetic properties and the determination of variation on both land and water have recently been taken up with great energy. The United States Coast and Geodetic Survey have several magnetic observatories that coöperate with foreign observatories and also with arctic and antarctic expeditions in the collection of magnetic data. There are also several vessels fitted with special instruments for determining magnetic elements at sea.

8. Variation does not remain the same in a given locality for any considerable time but undergoes a slow, progressive change continually. The line of no variation which now crosses the United States passed through London in the year of 1655 and through Paris in 1670. At present it is moving toward the west at the rate of about 1° in 15 years. Places east of this line have westerly variation which is gradually increasing, while to the west the variation is easterly and gradually decreasing as the line of no variation approaches.

9. Another deflection of the compass needle, called *dip,* was discovered by an English instrument maker late in the Sixteenth Century. He found that no matter how well-balanced a needle was, it would, after being magnetized, be deflected from the horizontal and point downward with its north end. Investigation disclosed the fact that in the southern hemisphere the south end of the needle would point down, but at places near the geographical equator the inclination to the horizontal was zero. By connecting all places where the dip is zero, the position of the *magnetic equator* is established. The magnetic equator does not

coincide with the geographical equator, but crosses it twice, once in longitude 12° W. and again in 168° W., but at no time does it recede more than 16° on either side. From the magnetic equator, dip increases gradually until the magnetic poles are reached where the needle points vertically downwards.

10. Dip, like variation, is subject to a gradual change. Lines connecting all points where the dip of the needle is the same are called *lines of equal inclination,* or *isoclinic lines,* and charts on which such lines are plotted are called *isoclinic charts.* As a rule, it will be found that the isoclinic lines run nearly parallel to the magnetic equator, and somewhat analogous to the geographical latitude parallels. Hence, in denoting the position of a place with reference to the dip, the term *magnetic latitude* is used.

11. Lines joining all places on the earth's surface, where the earth's magnetic intensity is the same, are called *isodynamic lines.*

12. Dip and magnetic intensity is of no particular importance to the aerial navigator though it is fitting that he has some knowledge of the subject. The tendency of the needle to incline downward is counteracted by the method used in its suspension, *as long as the compass card remains horizontal.* When a plane is banked, however, a different condition arises. This will be considered in detail somewhat later.

DEVIATION

13. As already stated, deviation of the compass is caused by the magnetic influence of the iron and steel used in the construction of the plane. It is the deflection of the needle from the magnetic meridian and is the most serious disturbance of the compass the pilot has to deal with. In planes where the compass is located very close to the engine, deviations are at times so great as to

render the compass almost useless, unless extraordinary precautions be taken to counteract the disturbance.

14. With reference to magnetism, there are two classes of iron, namely: *hard* and *soft*. Hard iron does not become magnetized by induction when exposed to the influence of some magnetic body but when once magnetized retains its magnetism permanently, or nearly so. Artificial magnets are made of hard iron. Soft iron becomes magnetized immediately on being exposed to the influence of some magnetic body, but such magnetism is only temporary and disappears when the influence of the magnetic body is removed. No iron, however, is entirely hard or soft.

15. Should the pole of a permanent magnet be brought in close proximity to a mass of soft iron, it will communicate a certain

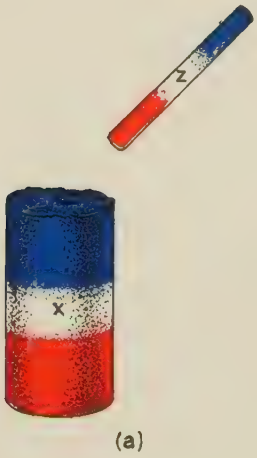


FIG. 37A

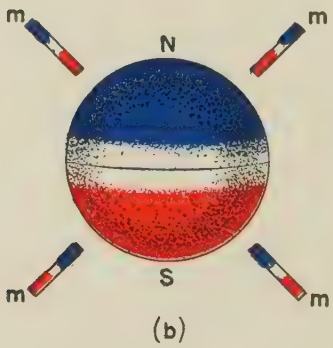


FIG. 37B

amount of its magnetism to the soft iron without losing any appreciable amount itself. Magnetism acquired in this manner is known as *induced magnetism*, or *magnetism by induction*, and the polarity of the soft iron part *nearest the inducing magnet* will be opposite to that of the inducing magnets nearest the pole. For

example, in Figure 37 (a), the mass of soft iron, y, is brought within the influence of the bar magnet, z, whose red pole is downward. The block will immediately become magnetized by induction, acquiring blue polarity in the upper end and red polarity in the lower.

16. As previously stated, the earth itself is a large magnet, with blue polarity in the northern hemisphere and red polarity in the southern hemisphere. It is evident from the preceding article that when a bar of soft iron, in the northern hemisphere, is held in a north-and-south direction with its north end inclined slightly downward, it will be feebly magnetized by induction from the earth and will have in its lower end a *red* pole, which, according to the law of attraction and repulsion, will repel the north end of the magnetic needle. In its upper end will be a blue pole which will attract the north end of the magnetic needle. Should the bar be reversed in direction, it will be found that the polarity of the bar is also reversed, the northerly end always being of red polarity, or opposite in character to the polarity of the earth. Figure 37 (b) represents the earth, and m a soft iron bar in different locations on the earth's surface, which has become magnetized by induction. It will be noticed conditions in the southern hemisphere are the reverse of those in the northern hemisphere. Again, if the bar be held *horizontally* in a north-and-south position it will still retain red polarity in its north end and blue polarity in its south end, but, the magnetism is much less in intensity. If the bar is held horizontally in an east-and-west position, *it will lose its magnetism entirely.*

17. Soft iron may be transferred into hard iron by hammering. Should a soft iron bar, of the kind referred to above, be held in the direction of the meridian and hammered, the induced magnetism will become permanent and the bar will thereafter act as a magnet irrespective of its position. The nature of its polarity will

depend on the direction in which it was held during the hammering. For example, a bar held in the direction of the meridian and hammered will have red polarity in the north end and blue polarity in the south end and this polarity will remain constant regardless of how the bar is turned later.

18. Since the material of which an airplane is constructed is composed of both soft and hard iron, it is evident that, while being built, the plane will acquire a magnetic character; firstly, by induction from the earth and, secondly, by the great amount of hammering to which it is subjected while under construction,

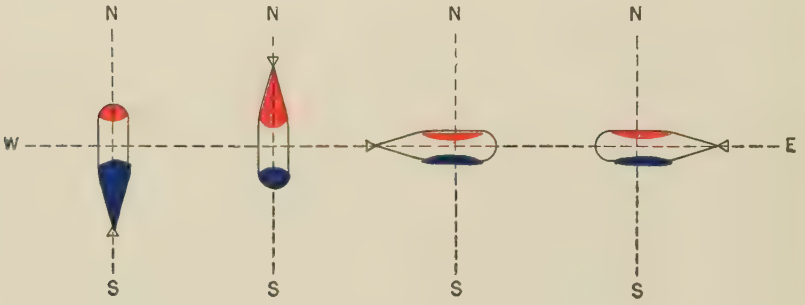


FIG. 38

rendering a certain amount of the induced magnetism permanent. Thus, a plane whose nose was north and tail south during building, will have red polarity in the forward part (figure 38) and blue polarity in the after part. The effect of this will be that the magnetism in the forward part of the plane will repel the north end of the compass needle, while the magnetism in the after part will repel the south end of the needle. Again, should the plane be built with her nose south and tail north, just the opposite condition would exist. Or, should the heading be east and west during building, the side nearest the north magnetic pole will have red polarity and the other side blue polarity.

19. It is well to remember that all red, or positive magnetism in the plane will act together from a common center, as will the blue, or negative magnetism. Thus, we have a condition exactly as if the polarity of each kind of magnetism was concentrated at one point. These centers of polarity are technically known as the *magnetic poles* of the plane.

20. The magnetism acquired by induction and made more or less permanent by hammering is known as *subpermanent magnetism* because it remains permanent or nearly so in all latitudes for a long period after building. It takes some time, however, before the magnetism of a ship becomes stable in amount, sometimes several months, but at the end of this period its amount and polarity may be considered permanent.

21. From the above, it is apparent that an airplane may be considered as a large magnet having red and blue polarity exactly the same as an ordinary magnet. The amount of subpermanent magnetism is influenced by the amount of iron used in the construction as well as by the size of the plane. Recent magnetic surveys conducted on a number of planes of various types and sizes indicate that the magnetic intensity is somewhat greater in a large ship than in a small one with about an equal percentage of iron used in their construction.

22. Magnetism of a temporary character is sometimes communicated to a plane by induction from the earth when the nose is kept in one direction for some time. This is known as *retentive magnetism* and may be acquired when a plane is left in the hangar in one position for a prolonged period. The effect of this magnetism is to increase or decrease the subpermanent magnetism, according to its polarity and the direction in which the plane has been standing. Retentive magnetism remains but a short time after the cause is removed.

23. Referring to figure 39, assume the plane to have been built

with her nose magnetic south. As shown in the figure, she will have subpermanent blue polarity forward and red polarity aft. Now, when heading in the direction of the magnetic meridian as at (1), there will be no deflection of the needle as both magnetic poles of the ship are in line with the horizontal directive force

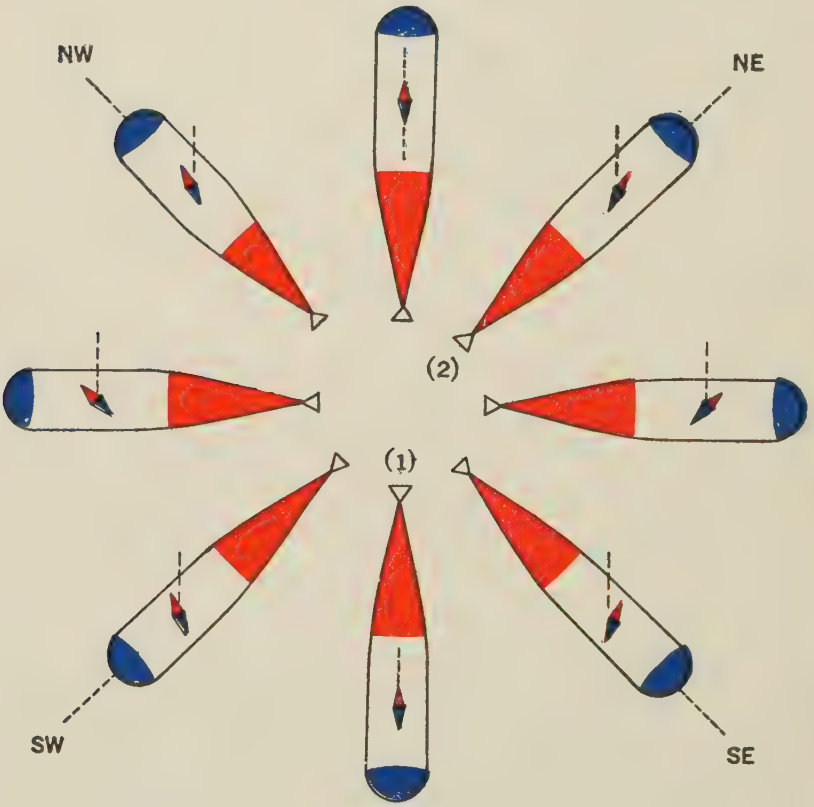


FIG. 39

controlling the needle. If the plane be headed northeast as in (2) the north end of the needle will be attracted by the blue polarity in the nose, resulting in easterly deviation which will gradually increase as the head is brought toward the magnetic east, on which heading the error will be greatest because the

magnetic poles of the ship are now at right angles to the normal direction of the needle and consequently exerting their maximum attraction. With the plane headed southeast, the deviation is still easterly but decreases until headed south, when it disappears. As the plane continues to swing toward the west, a westerly deviation will occur, increasing gradually until the maximum is attained when heading west. In the northwest quadrant the westerly deviation will gradually decrease as the plane is swung toward north.

24. From the foregoing, it is evident that deviation due to the subpermanent magnetism of the ship has opposite names and reaches its maximum value in opposite semicircles. For this reason, it is termed *semicircular deviation.*

25. For planes built with the nose north, the conditions described above would be reversed; then the maximum westerly deviation will occur when headed east and maximum easterly deviation when headed west. In a similar way all compasses are affected, and the nature of the resulting deviation will depend on the magnetic polarity of the ship. It should be remembered that no matter where the blue and red poles of the plane are situated they will, when both are on the line of the magnetic meridian, produce no deviation whatever; but, when in any other position they will produce an error whose maximum is reached when the line connecting the two poles is at right angles to the magnetic meridian.

26. For the purpose of investigating magnetism, the soft iron in an airplane may be conveniently divided into two classes; vertical and horizontal. All vertical soft iron in the plane becomes magnetized by induction from the earth. This magnetism, however, is transient in character, changing with latitude. Thus, for a plane in north magnetic latitudes, the upper ends of all vertical soft iron will have blue polarity, and the lower end, red polarity.

In southern magnetic latitudes this condition would be reversed and the same vertical soft iron would have red polarity in the upper and blue polarity in the lower ends. It is evident that the amount of this magnetism varies in the same proportion as the vertical force of the earth; in other words, it changes with the change in magnetic dip, being least at the magnetic equator and greatest at the poles.

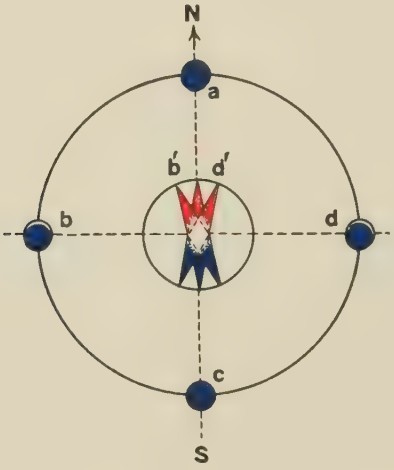


FIG. 40

27. The effect of vertical soft iron on the compass needle is illustrated in figure 40, where the magnetic meridian is represented by the line NS. Assume that a bar of vertical soft iron possessing blue polarity in its upper end is moved around the compass with its upper end at about the same level as the compass card. When the bar is in line with the needle, or on the magnetic meridian, it will cause no deviation; but when held on a line at right angles to the magnetic meridian, a maximum error is produced which is easterly when the bar is east of the meridian and westerly when west of it. It is evident that when the plane is turned about this iron will affect the compass in

exactly the same way as subpermanent magnetism. *The semicircle deviation, therefore, is the combined effect of subpermanent magnetism and transient magnetism of vertical soft iron.*

28. In the preceding articles, it was pointed out that a soft iron bar held in a north-and-south position will attain magnetism by induction from the earth but will lose this magnetism when turned in an east-and-west position. Horizontal soft iron of an airplane will acquire and lose magnetism in exactly the same way. The effect of horizontal soft iron on the compass is illustrated in

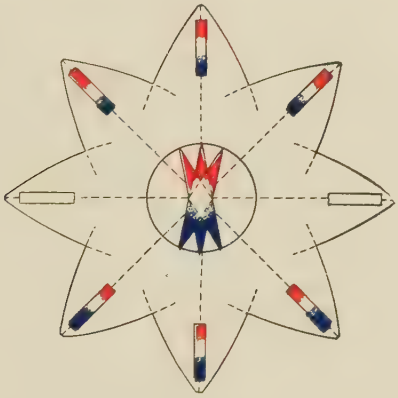


FIG. 41

figure 41, which represents a plane swung on different headings. When headed in the direction of the magnetic meridian (magnetic north or south), no deviation will occur as on these headings the magnetism of the horizontal bar will act in conjunction with the earth's horizontal force. When the head is brought to northwest or northeast, a maximum error is produced by the blue pole of the bar attracting the red pole of the compass needle. As the head is gradually brought to east or west, the bar will lose its magnetism entirely and have no effect on the needle on these headings. Continuing to swing to southeast or southwest, the magnetism of the horizontal soft iron bar will be reversed and a maximum

error will be produced on these headings by the red pole of the bar attracting the blue pole of the compass needle. This error will gradually decrease and disappear when the plane is swung south.

29. From the preceding article, it will be understood that when an airplane is heading north, east, south, or west there will be no deviation due to horizontal soft iron; but when heading on any other course an error will be produced that is greatest when headed on an intercardinal, or quadrantal (northwest, southwest, southeast and northeast) point. For the above reason, the error caused by transient magnetism of horizontal soft iron has become known as *quadrantal deviation.* This deviation has opposite names in adjoining quadrants and like names in opposite quadrants. For example, if the deviation caused by soft iron is easterly when headed N.E., it will be westerly when headed S.E., but easterly when heading S.W. Quadrantal deviation is constant in all magnetic latitudes, and, for a particular heading, the same in all parts of the world.

TURNING ERROR

30. When an airplane is banked another error is introduced for which there is no compensation. On a properly banked turn the compass card takes up the same inclination to the horizon as the plane itself and, in this position, the vertical component of the earth's magnetic force (dip), will cause the north point of the compass in northern latitudes to move downwards or toward the low wing. Take the extreme case of a plane headed north making a vertical bank to the right. As the ship banks, the right side of the compass card is lower than the left and the north end of the needle, being acted upon by dip, is pulled downward or, as it will appear to an observer, to the right. In other words, *the*

compass card is moving with the plane. Thus, when the plane has turned a given amount, say 45°, the compass will indicate a much smaller turn, possibly 20°, or even less. If the north point moves downward faster than the plane is swinging, an observer would believe the ship actually turning left instead of right.

31. In a like manner, in a plane making a left turn and banking sharply, the north point of the compass will be drawn downward, causing the card to swing left and turn with the ship.

When turning on northerly courses, the amount of the turn, as indicated by the compass, will be too small and may even be in the wrong direction.

32. Consider now a plane headed south and making a well-banked turn to the left. As the card becomes inclined to the horizon the north point is drawn downward causing the card to *swing right* and the turn to appear much greater and more rapid than it actually is. Had the turn been made to the right, the card would have *swung left.*

When turning on southerly courses the amount of the turn, as indicated by the compass, will be too large but always in the correct direction.

33. Compass readings are liable to be misleading, if not actually confusing, on well-banked turns. In thick weather, when the ground is not visible as a reference point, wide flat turns should be made. Compasses having weak magnets are liable to become

erratic when turning. In fact, numerous cases have been reported where the card has made several complete turns or actually started spinning in moderately bumpy weather.

34. A compass placed on board an airplane is subject to various magnetic disturbances and the resulting errors are collectively known as *deviation.* At the same time, the compass is acted on by variation, and the combined effect of both is commonly termed the *total compass error.*

CAUTION

35. Deviation and variation must not be confused. Variation, being caused by the earth's horizontal magnetic force, affects the compass alike on all headings, while deviation, being the result of magnetism in the plane itself, varies for different headings.

LOCAL ATTRACTION

36. Any disturbance due to iron, generators, metal buildings, tools, etc., in the immediate vicinity of the compass and which is not a part of the stationary equipment of the plane, is termed *local attraction.* This may also include the magnetic influence due to the locality in which the plane is operating—for example, when in close proximity to volcanic or iron bearing mountains.

37. The effect of magnetic material in the cargo may also be classed as local attraction. Besides the disturbances mentioned above, there are occasionally mysterious movements of the needle called *magnetic storms* or *perturbations,* which are not thoroughly understood. The Auroral phenomena is reported to have a marked effect upon the needle. Not only is the needle subject to unusual deflections during aurora, but the deflections seem to be irregular and synchronize more or less with the pulsations of the auroral beams or streamers. A number of reports by reliable

observers indicate that compass errors of as much as 12° have been noted during a marked auroral display. Observations, were, of course, confined to high latitudes.

38. There are also certain parts of the world in which the needle is reported to act more or less erratic, among which are Rockwell Island, in the North Atlantic; Cossack, North Australia; Coast of Iceland; east coast of Madagascar; Solomon Islands; Cape St. Francis, Labrador; Ascension and St. Helena.

CHAPTER VI

COMPASS COMPENSATION

GENERAL PRINCIPLES

1. The general principle of compass compensation is to counteract the magnetic disturbance causing the deviation by placing soft iron and magnets in the immediate vicinity of the compass, and in such positions as to set up an opposing disturbance thus neutralizing the effect of the plane's magnetism and leaving the magnetic needle comparatively free.

2. Assume a needle to be deflected from magnetic north to n, as in figure 42. According to the law of magnetic repulsion and attraction, the north-seeking end of a magnetic needle always

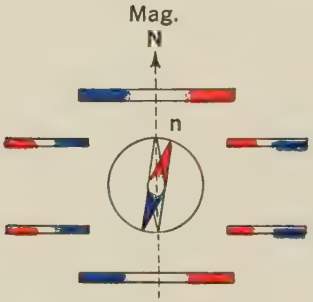


FIG. 42

possesses red polarity, and red polarity is repelled by red and attracted by blue. Then, in order to bring the needle back to the proper position, or what is the same, to counteract the effect of the plane's magnetism, a compensating magnet may be placed in any of the positions shown at a suitable distance from the compass. If the deviation be great, it may be necessary to use

two or more compensating magnets. Whether the magnets be used singly, in pairs, or in any other combination, the operation of compensation is simply a practical application of the law of magnetic attraction and repulsion.

3. The two principal errors of a compass requiring correction are the *semicircle deviation* and the *quadrantal deviation*. As previously stated, the semicircle deviation is the result of the subpermanent magnetism and induced magnetism of vertical soft iron. For the purpose of compensation, it is convenient to divide this error into two parts. The first part, which is the result of the magnetic force whose poles are in the fore-and-aft center line and which will affect the compass when heading on easterly or westerly courses, is commonly denoted by the letter B; while the second part, which represents a horizontal magnetic force with poles in line at right angles to the fore-and-aft center line and which affects the compass when heading on northerly and southerly courses, is commonly denoted by the letter C. The quadrantal deviation, the result of transient induced magnetism of horizontal iron, and which reaches its greatest value when heading on any quadrantal point, is usually denoted by D.

4. The letters, B representing the part of semicircle deviation affecting easterly and westerly courses; C the part affecting northerly and southerly courses; and D representing quadrantal deviation, are technically known as coefficients. In compass work it has been found good practice to compensate for D first, and then for C and B, in the order named.

5. As quadrantal deviation attains its greatest value on the quadrantal points, the plane is headed in the direction of one of them, for example, N.E. or N.W., as shown in figure 43; and, since the error is caused by transient induced magnetism of soft iron, it is necessary to correct it by an arrangement of soft iron usually in the form of hollow, soft iron spheres. (See practical

compensation.) These spheres are placed in brackets provided for them in the plane of the compass card. The error to be corrected being westerly in the N.W. and S.E. quadrants and easterly in the N.E. and S.W. quadrants, the spheres are placed

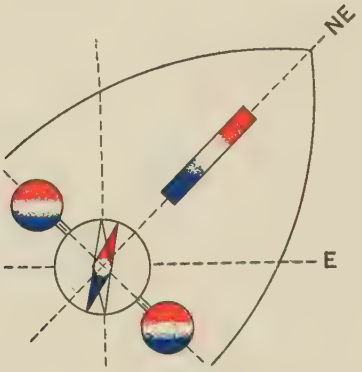


FIG. 43

athwartship and at an equal distance from the center of the compass, the proper distance being found by moving the spheres in or out on their respective brackets until the compass shows the correct quadrantal point on which the plane is headed.

6. The effect of the spheres when swung from one quadrantal point to the next is shown in figure 44, their polarity remaining unimpaired regardless of the direction the plane is heading. Their northern and southern hemispheres are always of the same magnetic character, *with their poles north and south,* regardless of how the spheres are revolved or how the plane is headed. A careful study of the figure will show how the magnetism of soft iron is thus compensated for.

7. The quadrantal deviation is constant for all magnetic latitudes, consequently its compensation remains constant everywhere, the induced horizontal force of the spheres varying in the same ratio as that of the horizontal iron causing the error.

8. To compensate coefficient C, the plane is headed magnetic

north. If the compass does not show exactly north, but is deflected to the west as shown in figure 45, center a magnet across the fore-and-aft line with its red pole west as shown. Begin by placing the magnet at some distance from the compass and gradually bring it nearer until the compass shows correct magnetic

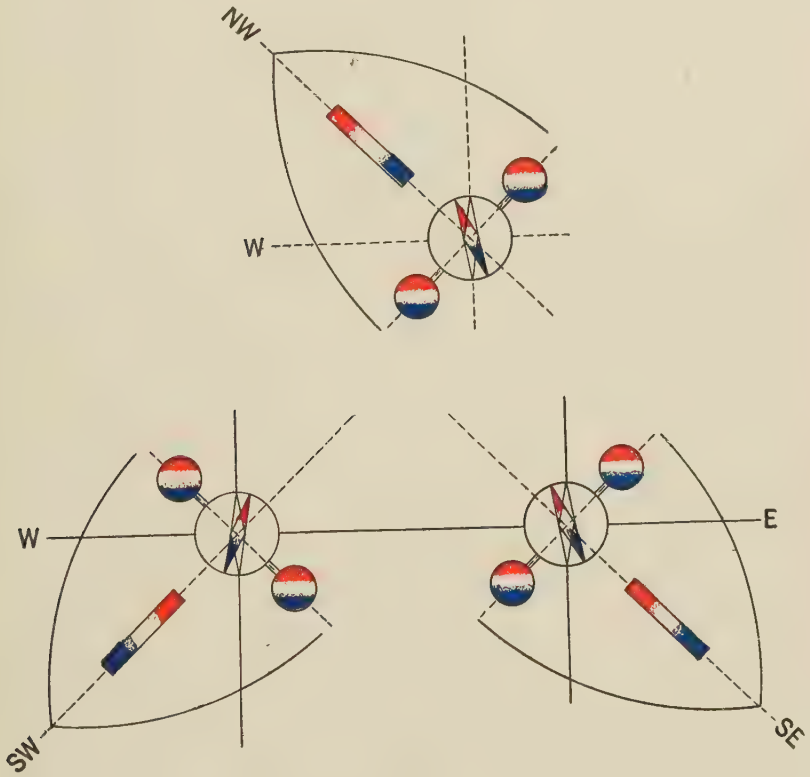


Fig. 44

north. The magnet is then secured in that position. Had the needle been deflected to the east instead of the west, the red pole of the magnet would have been pointed east instead of west. If the error is unusually large, it is good practice to remove only half of it on north, then head the plane south and repeat the operation, the second magnet being placed abaft the compass.

9. To compensate coefficient B, the plane is headed either east or west magnetic, and the head by compass noted. If, when

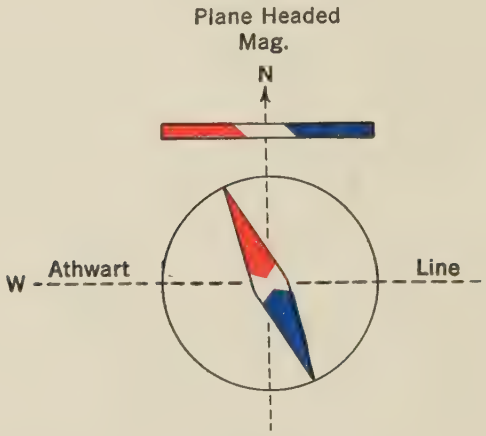


FIG. 45

heading magnetic east, the compass north is deflected to the left or west of magnetic north, as in figure 46, center a magnet across the athwartship line with its blue pole forward, finding by trial

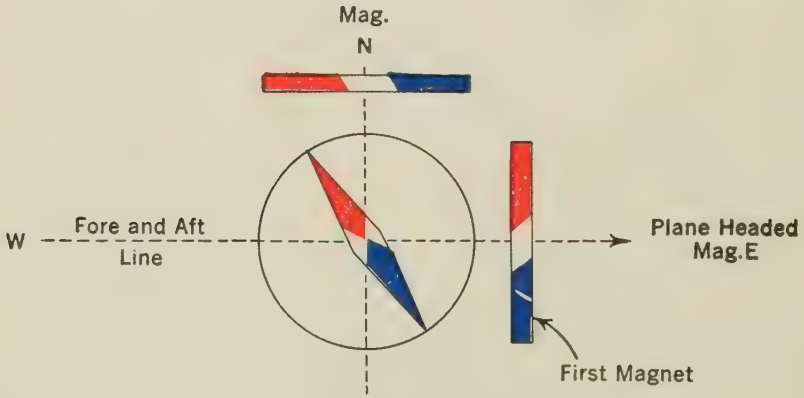


FIG. 46

the proper distance from the compass to correct the error. If the compass north were deflected to the east, the compensating magnet would, of course, be reversed. If the error is large, only

half of it is removed on east. The plane is then headed west and a similar operation is performed, using a second magnet on the opposite side of the compass.

REMARKS ON COMPENSATION

10. The foregoing, known as the rectangular method, sets forth the underlying principles of compensation and should be thoroughly understood before attempting extensive compass work. Modern compasses are fitted with compensating units containing receptacles which hold the fore-and-aft and athwartships magnets. Generally speaking, the receptacles are stationary and an increased or decreased magnetic force is obtained by using several small magnets instead of one large one, the necessary number being determined by trial. Regardless of the type of compensating unit, the principle is identically the same as where the magnets are secured about the compass as described above.

11. In extreme or unusual cases, it may be advisable to counteract most of the plane's magnetism, that is, obtain a partial compensation by placing magnets in the vicinity of the compass. Then, by use of the regularly fitted receptacles, complete the work. When placing the magnets in position, their centers must be exactly on lines or marks indicating the fore-and-aft and athwartships lines, and they should be perpendicular to their respective lines. It is immaterial where the magnets are placed so long as the principle is observed.

12. As stated before, the quadrantal compensation is good for practically all latitudes. This is not the case, however, with that part of the semicircle deviation due to induced magnetism of vertical soft iron. Since the amount of this magnetism depends on the vertical component of the earth's force, or dip, the resulting deviation will vary as the magnetic dip; being zero at the

equator and maximum in the vicinity of the poles. To compensate for this error successfully is a very difficult task, requiring skill and rare good judgment together with an intimate knowledge of the magnetic conditions of the ship. It may be successfully done, however, by use of a vertical soft iron bar, known as a *Flinders bar,* which is placed immediately before or abaft the compass. The gradual change in its magnetism, produced by a change of latitude, will offset the varying magnetism of vertical soft iron. In other words, the bar bears the same relation to vertical soft iron that the soft iron spheres do to horizontal soft iron.

PRACTICAL COMPENSATION

13. Very little soft iron, either horizontal or vertical, is used in the construction of the average airplane at present, hence aerial compasses are not fitted with brackets for the reception of quadrantal spheres. If the plane does not change magnetic latitude to any great extent, the following method of compensation may be considered to have corrected for both subpermanent magnetism and induced magnetism of vertical soft iron.

14. Attached to the bottom of the frame, and directly beneath the card, is the compensating unit where provision is made for the reception of a number of fore-and-aft and athwartships magnets.

15. The operation of compensating an ordinary aerial compass, where no unusual magnetic disturbance is present, may be summed up as follows:

(a) Head the plane magnetic north or south. If the north point of the compass is deflected to the east, insert one or more magnets in the athwartships receptacle, red ends east, increasing the number of magnets until the correct heading is shown. If the

north point is deflected to the west, the red ends of the compensating magnets would of course be west.

(b) Head the plane magnetic east or west. If the north point of the compass is deflected to the eastward, insert sufficient magnets in the fore-and-aft receptacle, red ends eastward, to cause it to read correctly. If the north point were deflected to the westward, the blue ends of the magnets would be placed eastward.

16. In the event of large deviations, the compensation should be checked on the opposite heading. For example, after having compensated on north, head the plane magnetic south. If there be any deviation, increase or decrease the number of magnets previously inserted, being careful to keep the red and blue poles all in the same direction. In the same manner check the work done on east and west.

17. It is well to remember that the main object of compensation is not to entirely remove the error, which is impossible, but rather to bring it within manageable limits. After being compensated, a compass is more uniformly sensitive, whereas a compass with large deviations has alternate sluggish and sensitive tendencies with certain directions of the plane's head.

SWINGING SHIP

18. After compensating a compass, there still remains a certain amount of deviation that must be known and tabulated. Since the amount of this deviation varies for different headings, it is necessary to determine the exact error at a number of points around the entire compass, usually every 15°. To do this, the plane is swung with her head on each successive point and the deviations found are tabulated and kept for use in correcting courses. The entire operation is called *swinging ship*.

19. When about to determine the deviation, the plane should be

in all respects ready for the air. No tools or other loose metal should be in the vicinity of the compass and all regular equipment must be in its customary place. Move the ship onto the field, well clear of all metal buildings, other planes, or anything that might set up a magnetic disturbance. Have a clear, level space of at least 75 to 100 yards in all directions. Bring the plane to normal flying attitude by raising the tail and secure in that position.

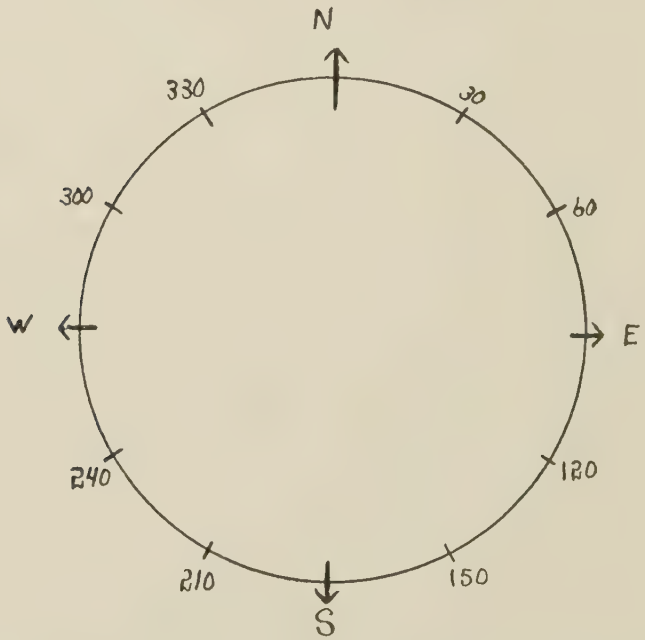


FIG. 47

20. Probably the most important point in both compensation of compasses and swinging ship is getting the plane on the correct magnetic heading. On many airports a *deviation clock* will be found, consisting of a circular cement slab about 40 or 50 feet in diameter, and having a well marked center. See figure 47. The circumference of the circle is marked as shown, and by using a piece of cord or string running from opposite sides, a line may

be laid down in any desired magnetic direction. For example, it is desired to head a plane magnetic north. The ship is moved onto the circle so the compass will be over the central point. A string is stretched between N and S. A Plumb bob is dropped from the tail skid and another from the center of the propeller spinner. The ship is now carefully turned until both plumb bobs touch the string running from the north to the south side of the circle, when she will be headed correct magnetic north. Other magnetic headings are obtained in the same way. See figure 48.

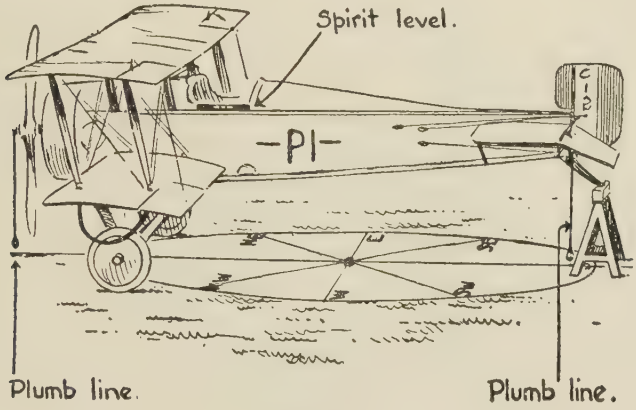


FIG. 48

21. A temporary circle of the above type may be readily constructed at any time. Using a flat top compass as a center, a few wooden pegs and a long string, locate the magnetic meridian by stretching the string across the top of the compass and moving the ends in azimuth until the string lies north and south, when pegs should be driven as marks. Locate additional points in the same manner every 30° and mark with pegs. Care must be taken that no iron or other metal is in the immediate vicinity while the work is in progress.

22. Another method of using the deviation clock is to erect markers on known bearings. A point is selected which will give a clear

and unobstructed view in all directions. Using this point as a center, markers are erected or painted on convenient buildings, and their magnetic bearing carefully recorded. When a plane desires to compensate or swing ship, it is placed so its compass will be over the central mark. Then, by using plumb bobs fore-and-aft and lining them up on the marker, much like sighting a gun, the required magnetic heading is obtained.

23. A third method, and one requiring no special equipment except a spare flat top compass, is to make one end of a long string

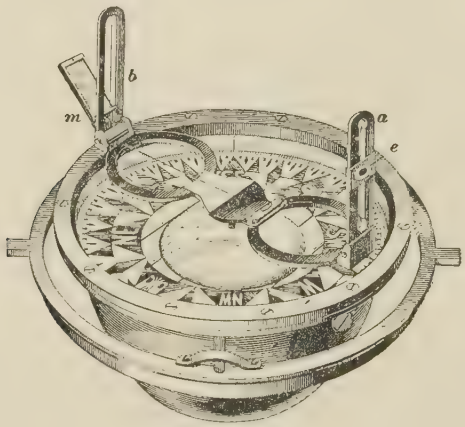


FIG. 49

fast to the tail skid. Carry the string forward, under the ship and 30 or 40 feet in front of it. Drop a plumb bob from the center of the propeller spinner. When the string is made taut and just touching the plumb bob, slip the compass under it and note the heading. The extra compass should be at least 25 or 30 feet from the plane to avoid being influenced by its magnetism.

24. Where compasses are being swung regularly, a field compass fitted with sight vanes, or surveyors' transit may be used. The field compass, figure 49, is placed 50 to 100 yards in front of the plane and *exactly on the center line*. The center line may be

located by dropping two plumb bobs, as explained above, and getting them in line from the field compass position. A bearing is then taken of the ship's exact center. This bearing reversed will be the correct magnetic heading. For example, in figure 50, the bearing of the ship's center, S, from field compass located at

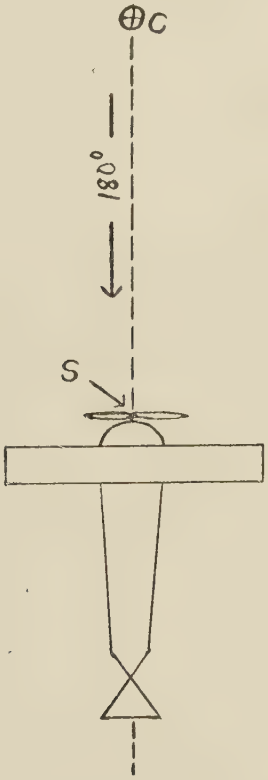


FIG. 50

C, is 180°. Reversing this bearing, the ship's magnetic heading is found to be 0°.

25. Professional compass adjusters prefer to use an instrument especially constructed for taking bearings known as the *pelorus*, or *dumb compass*. It consists of a metal compass dial usually graduated in points as well as single degrees. Attached to the

same pivot as the dial is a metal bar, aa figure 51, fitted with sight vanes c and d, and a reflector r. The bar and dial can be clamped in any desired position. The entire instrument is contained in a wooden box and suspended on gimbols. The box is supported on folding legs, much like a camera stand. A screw fitted in the supporting arm b, adjusts the lubber line to the ship's

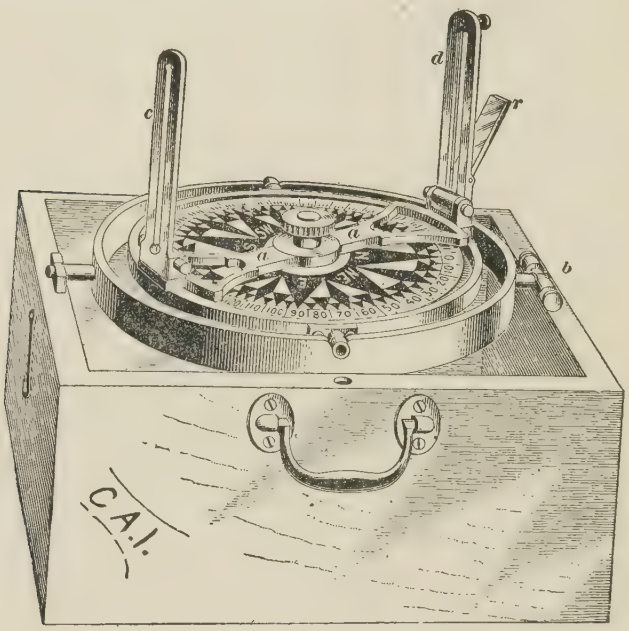
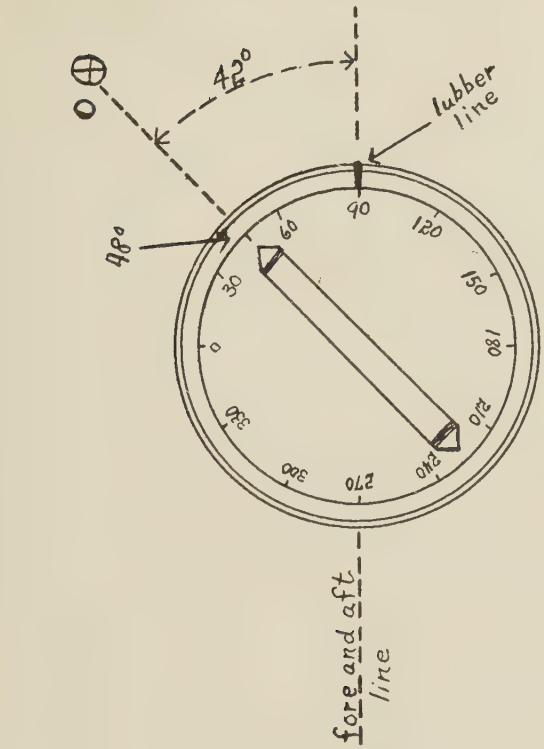


FIG. 51

head. The pelorus is set up on the center line of the plane, above the upper wing, so an unobstructed all-around view is obtained. The lubber line is adjusted to the plane's centerline by bringing the sight vanes on the fin and revolving disk until correct alignment is obtained.

26. To swing the plane to any magnetic heading by using the pelorus, the sight bar and bearing plate are clamped at an angle to the known magnetic bearing of some distant object, this bear-


42°
48°
lubber line
fore and aft line
0
30
60
90
120
150
180
210
240
270
300
330

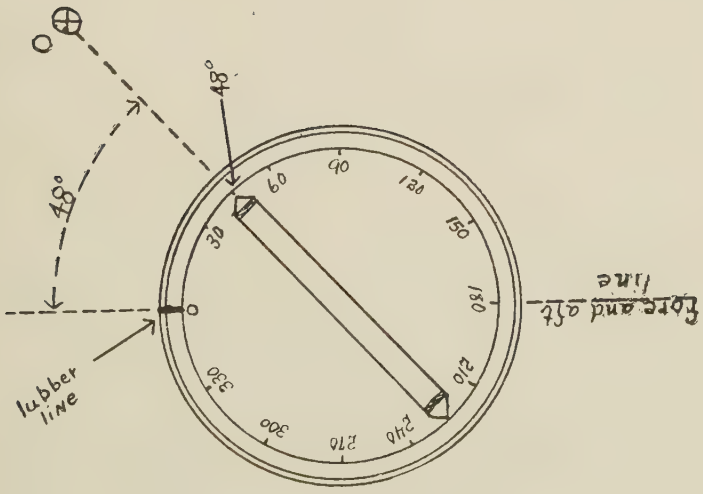

48°
48°
lubber line
fore and aft line
0
30
60
90
120
150
180
210
240
270
300
330

FIG. 52

ing having been taken from the map or determined by methods to be described later. The tail is then moved around until the sight vanes cut the object, when the ship will be on the required heading. For example, the magnetic bearing of the distant object, O, figure 52, is known to be 48°, and the plane is to be headed magnetic north. With the bearing plate set at north (the desired heading) and the sight vanes clamped at 48°, the plane is swung until the object is cut by the sight vanes. The ship is now on the desired magnetic heading. To head the plane magnetic east, the bearing plate is revolved and set on east, the sight vanes

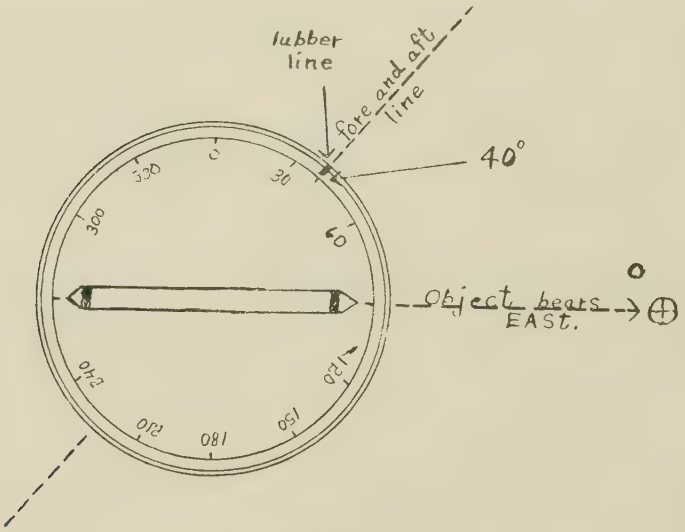


FIG. 53

are left clamped on 48°. The plane is again turned until the sight vanes cut the object. Any desired heading may be obtained in the same manner, the bearing plate being set for the required heading and the sight vanes clamped on the known bearing of the distant object.

27. The pelorus may also be used to find the bearing of an object from the compass in the plane. To do this, the bearing plate is

set on the heading shown by the compass and the sight vanes are revolved until they cut the object. The bearing shown is *the compass bearing*. For example, in figure 53, a plane, heading 40° by compass, wishes the compass bearing of object O. To obtain this *the bearing plate is set at 40°*, and the sight vanes revolved until they cut the object, when its compass bearing is read off.

28. A pelorus used in compass work is usually fitted with a small removable magnetic needle which fits on the dial and sight bar pivot. Prior to compensating or swinging, the pelorus is set up on the ground, over the exact spot to be occupied by the plane later. The needle is then set in place and the direction of the magnetic meridian determined. By setting the bearing plate to correspond with the needle, the bearing of the distant object to be used in swinging may be determined in the usual way.

29. The correct magnetic bearing may also be conveniently found *after the ship is swung* by taking the mean of all compass bear-

Head by Compass	Bearing of Object (Compass)	Bearing Referred to East Point
1..... N.	3°	E. 87° N.
2..... 45°	2°	E. 88° N.
3..... E.	1°	E. 89° N.
4..... 135°	0°	E. 90° N.
5..... S.	358°	E. 92° N.
6..... 225°	357°	E. 93° N.
7..... W.	359°	E. 91° N.
8..... 315°	0°	E. 90° N.
Sum of bearings = 720°.		

ings of the object. In cases where bearings are on both sides of the north point, they should be referred to the east or west point to prevent any mistake being made in finding the magnetic bear-

ing of the object. In the following table it will be noted all bearings have been referred to the east point.

Mean of all bearings $= \frac{8}{720} =$ E. 90°N. = N., which is the correct magnetic bearing of the distant object.

30. The object selected on which to swing ship should be well defined. It should be sufficiently far away that no sensible error will result when turning the plane from one heading to the next. If care is taken not to change position when turning, objects ½ mile away may be used.

31. Having decided on the method to be used, the plane is swung to each magnetic heading, and the heading by compass carefully noted. The difference between the correct magnetic heading and that of the compass will show the error, or, in other words, the deviation for each heading. The data is entered in a form similar to that shown below, the first column showing the correct magnetic heading, the second, compass heading and the third, deviation.

TABLE I

Correct Magnetic	Compass	Deviation
N.	358°	2° E.
30°	25°	5° E.
60°	57°	3° E.
E.	88°	2° E.
120°	119°	1° E.
150°	150°	0°
S.	181°	1° W.
210°	212°	2° W.
240°	245°	5° W.
W.	272°	2° W.
300°	300°	0°
330°	329°	1° E.

32. The correct naming of the deviation is very important and the following rule should be thoroughly understood and memorized:

Rule: *Deviation is east when the north point of the compass is deflected to the east, or right, of magnetic north; it is west when*

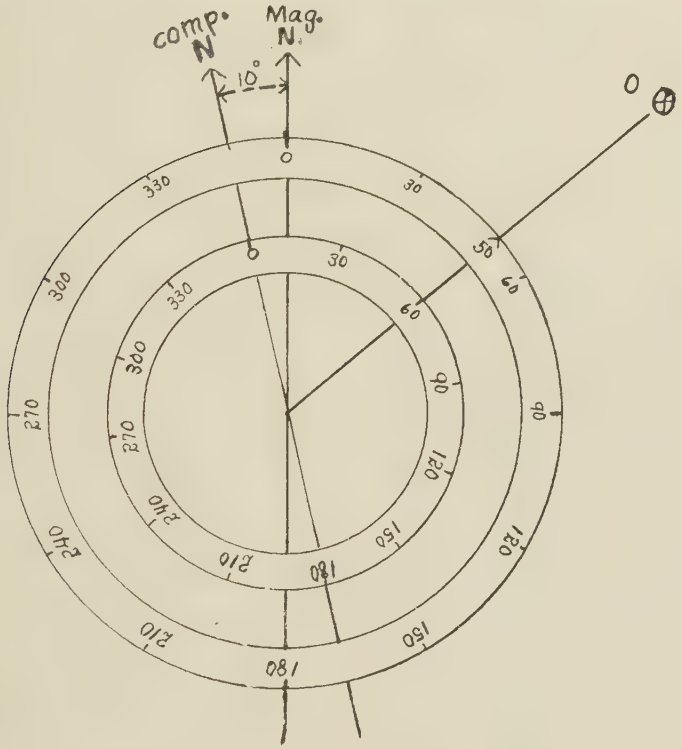


Fig. 54

deflected to the west, or left, of magnetic north; or, if the correct magnetic bearing or heading lies to the right of the compass bearing, deviation is easterly; if to the left, deviation is westerly.

33. When first looking over the above rule, the first and last part seem to contradict each other. In figure 54, the outer circle represents magnetic direction, while the inner circle represents com-

pass direction. Now, according to the first part of the rule, the deviation is westerly because *the compass north is deflected to the left, or west of magnetic north.* For the purpose of illustration, assume the bearing of object O to be 50° magnetic, but by compass it bears 60° as shown. As the magnetic bearing lies to the left of the compass bearing, according to the last part of the rule the deviation is westerly. The entire rule is therefore evidently correct.

34. Referring to table No. 1, when the plane was headed 30° magnetic, the heading by compass was 25°. According to the rule, the deviation for this heading is $30° - 25° = 5°$ easterly, because the *magnetic heading is to the right, or greater than the compass heading.* Again, when the plane was headed magnetic 240°, the compass read 245°. The deviation on this heading is therefore $245° - 240° = 5°$ westerly, because the *magnetic bearing lies to the left, or is less than the compass bearing.*

35. Where deviations are small, as they usually are in a well compensated compass, it is sufficient to determine the error for

Head by Compass	Bearing by Field Compass		Head by Compass	Bearing by Field Compass
North	182°		South	359°
15°	195°		195°	15°
30°	207°		210°	32°
45°	220°		225°	48°
60°	233°		240°	65°
75°	247°		255°	81°
East	260°		West	98°
105°	277°		285°	112°
120°	294°		300°	126°
135°	311°		315°	139°
150°	327°		330°	153°
165°	343°		345°	168°

every 30°. For navigational purposes, fractions of degrees are rejected, deviations being worked to the nearest whole degree. 36. After the plane has been swung and the deviations found, they are entered on the *deviation card* which should be kept in the plane for handy reference. A very simple form of card is shown in table II, made up from data obtained by use of a field compass as follows:

TABLE II

DEVIATION CARD

For magnetic compass No. 21784 of Waco plane, adjusted at Municipal Field, Tampa, Florida.

DATE: June 15, 1927 E. A. RICH, *Pilot.*

Head by Compass	Deviation		Head by Compass	Deviation
0°	2° E.		180°	1° W.
15°	0°		195°	0°
30°	3° W.		210°	2° E.
45°	5° W.		225°	3° E.
60°	7° W.		240°	5° E.
75°	8° W.		255°	6° E.
90°	10° W.		270°	8° E.
105°	8° W.		285°	7° E.
120°	6° W.		300°	6° E.
135°	4° W.		315°	4° E.
150°	3° W.		330°	3° E.
165°	2° W.		345°	3° E.

CAPTAIN L. A. YANCEY, *Adjuster,*
715 Continental Bldg., Baltimore, Md.

Each field compass bearing is reversed by the addition or subtraction of 180° and considered as the correct magnetic heading. The compass and magnetic headings are then compared, as previously explained, the deviations found and entered as shown.

37. Figure 55 shows the deviation card used by the Pioneer Instrument Company of New York. It is printed on heavy cardboard and convenient pocket size.

Airplane No.

FOR	N	330	300	W	240	210
STEER						
FOR	S	150	120	E	60	30
STEER						

Date Swung by

FIG. 55

38. A *deviation diagram* is a graphic representation of the known compass errors. There are several kinds in general use, the best of which is probably Napier's Diagram, named after its inventor. A diagram is useful when the errors are large and great accuracy is desired in obtaining the deviation between the tabulated values. Should a diagram be needed a very practical substitute may be constructed on a piece of cross-section paper. Each heavy line is marked from top of the sheet down starting with 0°, 15°, 30°, 45°, etc., until 345° is reached. A vertical line is drawn near the center of the sheet to represent the magnetic heading. From the vertical line, on the horizontal lines, and on any desired scale, lay off deviation corresponding to the heading of that line, easterly deviations to the right and westerly deviations to the left, and draw a flowing curve through these points. The distance from the vertical line to the curve, according to the scale, will give the deviation with considerable accuracy for any heading of the plane. For example, a curve of the deviation in table II is shown in figure 56. The error for any heading may be found by measuring the horizontal distance from the vertical line to the curve. Thus, the deviation for 45° would be the distance A which equals 5° west.

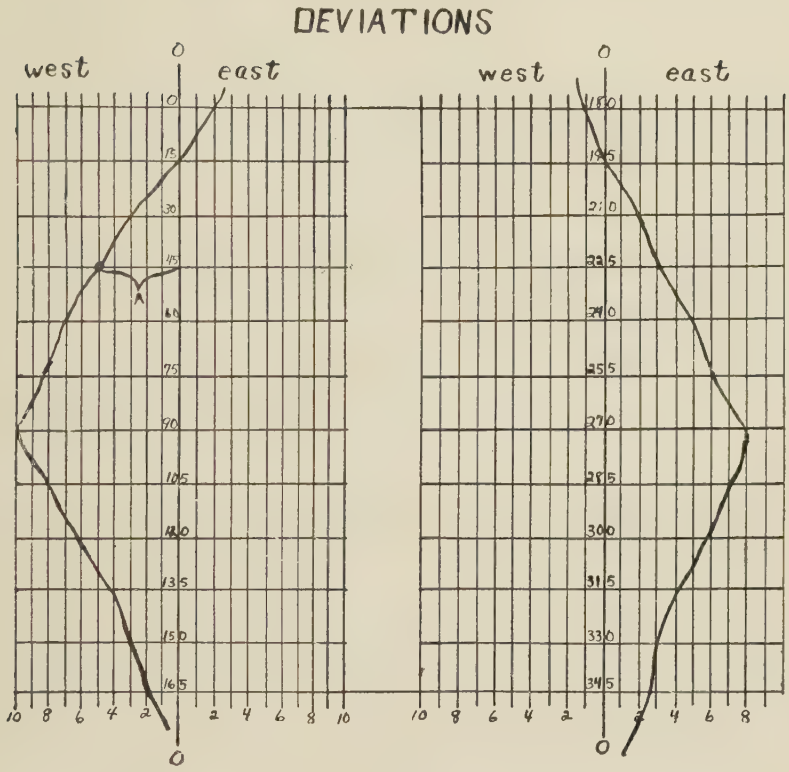


FIG. 56

REMARKS

39. It should be borne in mind that deviations, regardless of the method found, belong only to the compass by which the observations were obtained. Furthermore, the deviations are of no value if the compass be moved to some other part of the ship. If there be two or more compasses, each must have a separate card of deviations, clearly marked to indicate the instrument to which they belong. It is evident that while swinging ship, deviations of all the compasses may be obtained at the same time if the heading indicated by each is noted and tabulated during the swinging.

40. Deviations should be constantly checked and discrepancy of

the card should be investigated immediately. The pilot should know the magnetic direction of the runways on the home field, and note the compass head at each take off. He should also be familiar with other magnetic bearings in the vicinity, for instance, the bearing of a distant building from the field, the direction of a well defined roadway; the line of bearing of the hangars, etc. It is essential that a pilot flying mail or express check his compass constantly. Cases are on record where magnetic material in the cargo have caused sudden and unusually large deviations to appear. A little care in the stowage of the cargo would help, but constant vigilance on the part of the pilot is the real safeguard. Where a regular route is flown constantly, some provision should be made for checking the compass error on the course to be steered before leaving the ground, or immediately after taking to the air. It is a simple matter to erect a marker on the magnetic bearing corresponding to the mean of the courses to be steered, and in thick weather at least, check the compass before taking off, or immediately after taking off to fly low over the field on a known range.

EXAMPLES FOR PRACTICE

Example 1. By use of a deviation clock, a plane was headed magnetic east. While thus headed the compass read 84°. What was the deviation on this point? Ans. 6° E.

Example 2. A plane was headed North by compass. A field compass was placed in front of the ship on her fore-and-aft center line and reciprocal bearing taken which was 174°. What was the deviation for this heading? Ans. 6° W.

Example 3. The bearing of a distant object was found to be 350° magnetic. If a pelorus is used to head the ship magnetic N.E., what will be the angle between the bearing of the distant object and the ship's fore-and-aft line? What will be the angle

between the fore-and-aft line and the magnetic meridian? (1) Ans. 55°. (2) Ans. 45°.

Example 4. A plane was swung from North to East for deviation and the following data obtained. Prepare a card showing the deviations for the various headings.

Head by Compass	Bearing Field Compass
1..... North	185°
2..... 15°	198°
3..... 30°	210°
4..... 45°	222°
5..... 60°	235°
6..... 75°	247°
7..... 90°	260°

Ans.

Deviation Card	
Head	Deviation
0°	5° E.
15°	3° E.
30°	0°
45°	3° W.
60°	5° W.
75°	8° W.
90°	10° W.

Example 5. A pelorus was used in swinging a plane for deviations and the following data obtained:

Head by Compass	Compass Bearing of Distant Object
N.	28°
30°	33°
60°	37°
90°	40°
120°	36°
150°	33°
S.	31°
210°	28°
240°	25°
270°	22°
300°	24°
330°	27°

What was the correct magnetic bearing of the distant object? Prepare a card showing the deviations for the various headings.

(1) Ans. The correct bearing was 30.3° magnetic (30°).

(2) Ans.

Head by Compass	Deviation		Head by Compass	Deviation
North	2° E.		South	1° W.
30°	3° W.		210°	2° E.
60°	7° W.		240°	5° E.
90°	10° W.		270°	8° E.
120°	6° W.		300°	6° E.
150°	3° W.		330°	3° E.

CHAPTER VII

CORRECTION OF COURSES

1. When about to make a flight from one place to another, both of which are shown on the map, one of the first things to be done is to find the course to steer by compass in order to follow the shortest, safest and most convenient route between them.

2. As the compass is affected by variation and deviation, there are three distinct north and south lines or meridians to be considered: (1) that shown on the map, known as the *true* or *geographical meridian;* (2) the *magnetic meridian;* and (3) the *compass meridian.* Consequently there are three kinds of courses. (1) *True course,* or the course measured from the true meridian on the map; (2) *magnetic course,* which is the true course corrected for variation; and (3) the *compass course,* which is the magnetic course corrected for deviation. The compass course is also the true course corrected for total compass error.

3. As previously stated, the course is the angle between the plane's fore-and-aft line and the meridian. Let t, figure 57, represent the true meridian, m the magnetic meridian, c the compass meridian. For a plane bound from o to x, the true course would be t o x which is the angle between the true meridian and the plane's fore-and-aft line. The magnetic course would be m o x which is the angle between the plane's fore-and-aft line and the magnetic meridian. The compass course (course to steer by compass) would be c o x which is the angle between the fore-and-aft line and the compass meridian. It is evident that should there be no variation, the true course and the magnetic course will be identical. Again, should there be no deviation, the com-

pass and magnetic course would be the same. This is seldom the case, however, and it is usually necessary to apply both variation

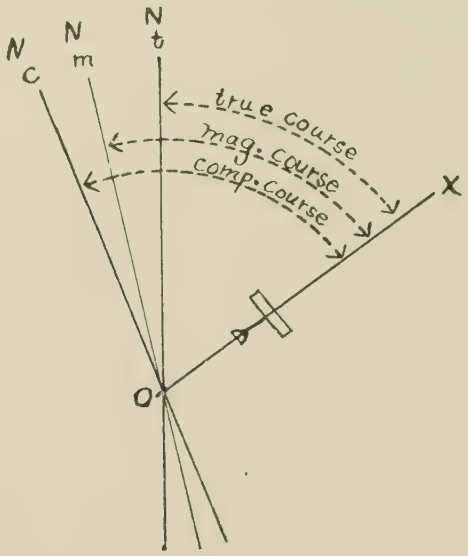


FIG. 57

and deviation to the course taken from the map to determine the corresponding compass course.

RULE: *To convert a true course into compass course, add westerly variation and deviation, and subtract easterly variation and deviation.*

4. To illustrate the above rule, note carefully the following worked out examples:

NOTE: Until thoroughly familiar with compass work, it is advisable to make a rough sketch of the problem. First, lay down the true meridian, then the magnetic meridian, east or west of the true, according to the variation. From the magnetic meridian lay off the compass meridian, east or west of it according to the deviation.

Example 1. The true course found from the map to the nearest airport is 60°, assuming variation to be 12°W., and the deviation 4°W., what would the compass course be? See figure 58.

Solution:		
	True course	= 60°
	Variation	= 12° W. (add)
	Magnetic course	= 72°
	Deviation	= 4° W. (add)
	Compass course	= 76° = ans.

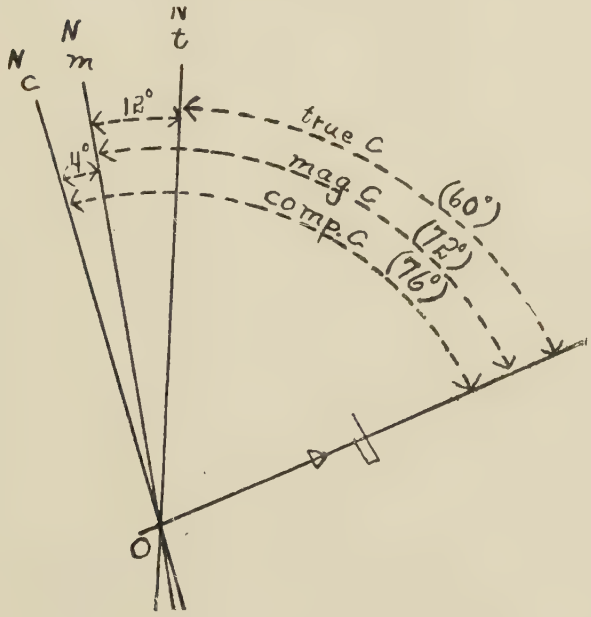


Fig. 58

Example 2. The true course as found from the map is 85°. Inspection of the variation chart shows a variation of 8°E. Deviation, 3°E. What is the compass course? See figure 59.

Solution:		
	True course	= 85°
	Variation	= 8° E. (subtract)
	Magnetic course	= 77°
	Deviation	= 3° E. (subtract)
	Compass course	= 74° = ans.

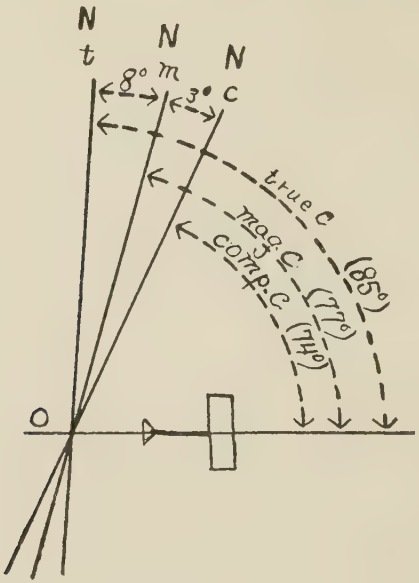

N
t
N
m
N
c
8°
3°
true C (85°)
mag. C (77°)
comp. C (74°)
O

FIG. 59

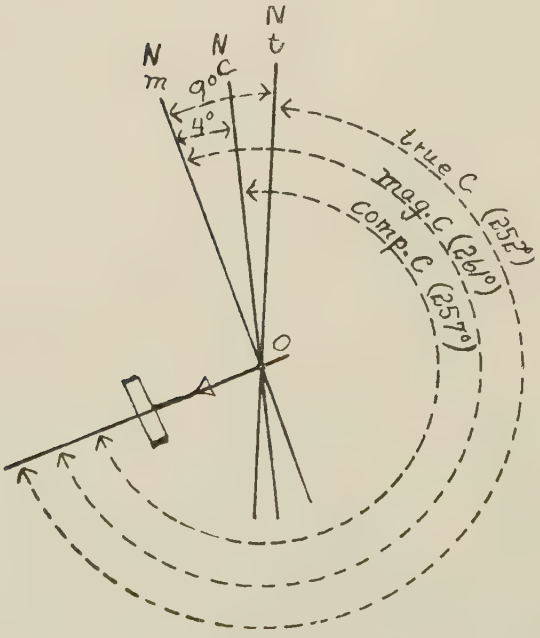

N
t
N
m
N
c
9°
4°
true C (252°)
mag. C (261°)
comp. C (257°)
O

FIG. 60

Example 3. The true course as found from the map from Easton, Pa., to Harrisburg is 252°. The mean variation, as shown by a variation chart, is 9°W. Assuming the deviation to be 4°E., what is the compass course? See figure 60.

Solution:			
	True course	= 252°	
	Variation	= 9° W.	(add)
	Magnetic course	= 261°	
	Deviation	= 4° E.	(subtract)
	Compass course	= 257°	= ans.

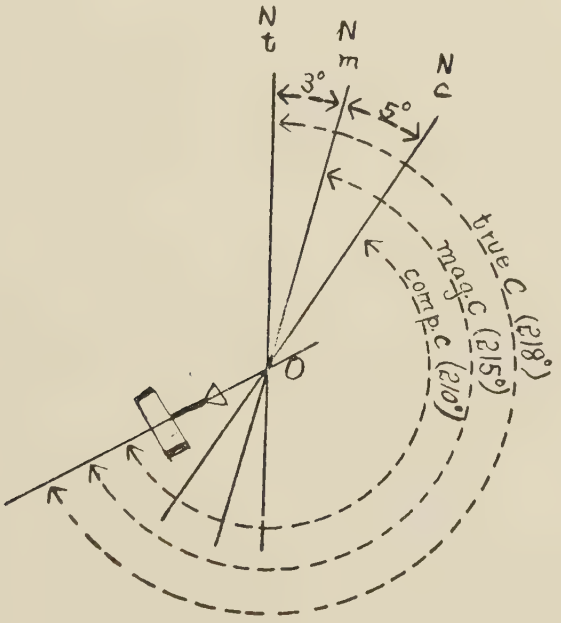


FIG. 61

Example 4. The true course from the Municipal field at Chicago to the field at Springfield, Ill., as found from the map, is 218°. The variation is found to be 3°E. Assuming the deviation to be 5°E., what is the compass course? See figure 61.

Solution:
True course = 218°
Variation = 3° E. (subtract)
Magnetic course = 215°
Deviation = 5° E. (subtract)
Compass course = 210° = ans.

Example 5. The true course from field A to field B is 50°. Variation in the locality is 5°W. Deviation is assumed to be 6°E. What is the compass course? See figure 62.

Solution:
True course = 50°
Variation = 5° W. (add)
Magnetic course = 55°
Deviation = 6° E. (subtract)
Compass course = 49° = ans.

5. Compass courses may be converted into true courses by the following rule:

RULE: *To convert a compass course into a true course, add easterly variation and deviation and subtract westerly variaton and deviation.*

Example 1. A plane had flown some distance on compass course 60°. Deviation 7°W., variation 5°E. What true course was she making good? See figure 63.

Solution:
Compass course = 60°
Deviation = 7° W. (−)
Magnetic course = 53°
Variation = 5° E. (+)
True course = 58° = ans.

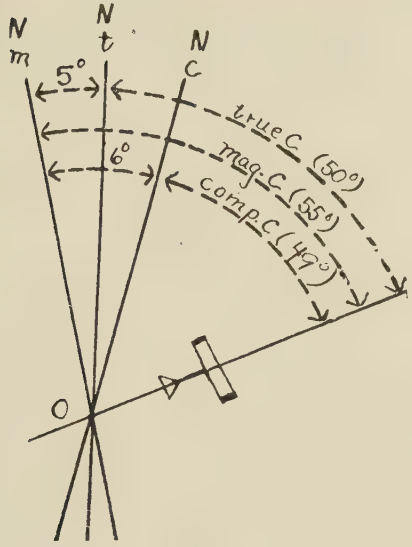

N
m
N
t
N
C
5°
6°
true C. (50°)
mag. C. (55°)
comp. C. (49°)
O

FIG. 62

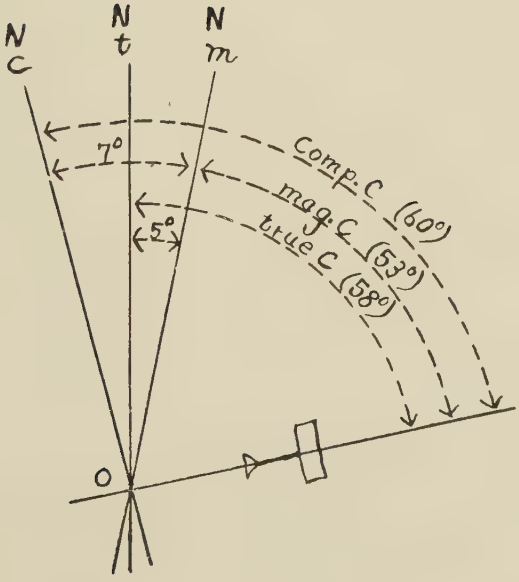

N
C
N
t
N
m
7°
5°
comp. C. (60°)
mag. C. (53°)
true C. (58°)
O

FIG. 63

Example 2. The compass course from the field at Terre Haute, Ind., to the field at St. Louis, Missouri, was 251°. The mean variation was 4°E. Assuming there is no deviation, what is the true course? See figure 64.

Solution:

Compass course	=	251°
Deviation	=	0°
Magnetic course	=	251°
Variation	=	4° E. (+)
True course	=	255° = ans.

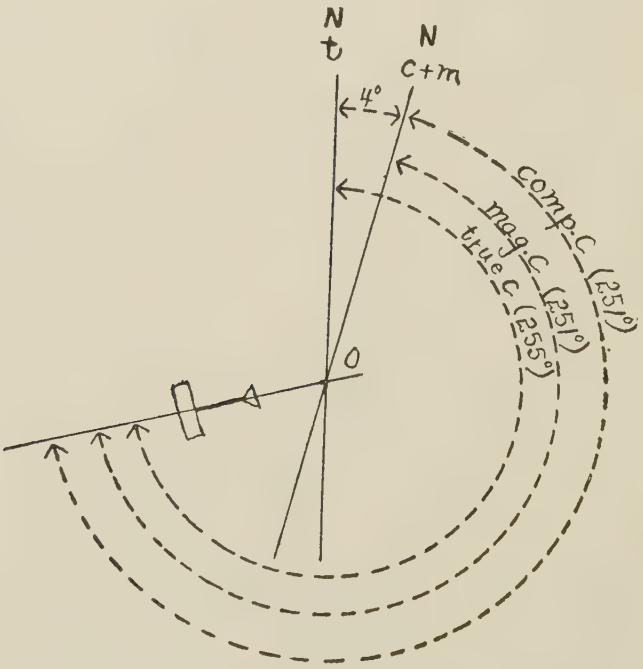


FIG. 64

Example 3. The compass course from Champaign, Ill., to the Municipal field at Chicago was 15°. The variation was 3°E., deviation 6°W. What was the true course? See figure 65.

Solution: Compass course = 15°
Deviation = 6° W. (−)
Magnetic course = 9°
Variation = 3° E. (+)
True course = 12° = ans.

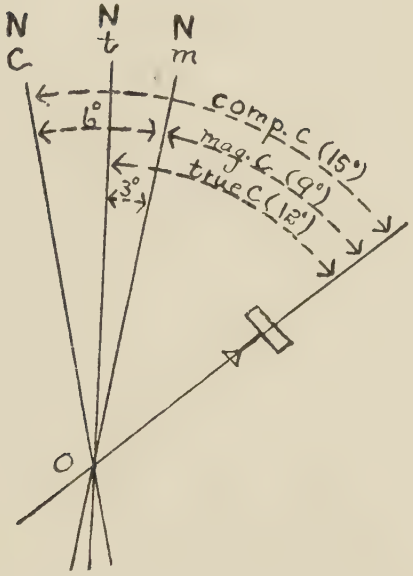


FIG. 65

EFFECT OF THE WIND

6. In the above examples no allowance was made for effect of the wind, while in actual practice this correction is equally as important as variation and deviation.

7. The speed a plane makes through the air is known as *air speed,* while the speed made with reference to some point on the ground is called *ground speed.* In perfectly still air, the air speed and ground speed would be equal. This condition seldom prevails, however, and it is usually necessary to make a correction to the course to overcome the effect of the wind.

8. When a plane flies in moving air (wind), her rate of travel is necessarily affected by it and, in general, both the speed *over the ground* and the direction in which she would have otherwise moved are greatly altered. If flying directly with or against the wind, the ground speed only is affected. In the former case, the ground speed will be increased over the air speed an amount equal to the velocity of the wind, while in the latter case, the ground speed will be reduced the same amount.

9. Wind is named according to the direction from which it blows. Hence, a wind from the northwest is termed a northwest wind. The direction a plane is being moved *by the wind* is called *set;* thus, a northwest wind will cause a plane to be set southeast. The distance a plane has been blown from the desired course, or destination, is termed *drift*. *Leeway* is the correction applied to the course to overcome set and drift and enable the plane to follow the desired true course.

10. Before entering into the solution of set and drift problems, a clear understanding of Newton's first and second laws of motion, sometimes known as the laws relating to the connection of forces with motion, will be useful. In order that this knowledge may be easily attained, a few fundamental principles of mechanics will be given.

11. When a body changes its position with regard to some fixed object, it is said to be *in motion* with relation to that object; when no such change is taking place, it is said to be *at rest* with relation to that object. Thus, a train that passes slowly by a station is in motion with relation to the station. On the other hand, if a man on the train walks or runs from the front to the rear, that is in a direction opposite to that in which the train is going and with the same speed, he will be in motion with relation to the train, but at rest with relation to the station; since, until

he stops running, he will be directly over the spot on the ground at which he was when he started.

12. When an object moves from one position to another, it describes either a straight or curved line connecting the two positions, known as the *path* or *track*. The rate at which the body moves from one position to another is called its *velocity*. Velocity may be defined as the distance passed over in a given time. With reference to the motion of airplanes, velocity is usually termed *speed*.

13. Motion that takes place along a straight path is termed *rectilinear motion*, and may be represented on a sheet of paper by a straight line; the direction of the line may represent the direction of motion, while the velocity is conveniently shown by its length. By representing the motion of bodies in this manner certain relations may be established by which problems connected with such motions may readily be solved by construction.

14. Newton's first and second laws of motion, referred to above, are as follows:

1. *All bodies continue in a state of rest, or of uniform motion, in a straight line unless acted upon by some external force that compels a change.*

2. *Every motion, or change of motion, is in proportion to the acting force and takes place in the direction of the straight line along which the force acts.*

15. From what has gone before, certain definite conclusions are established. Thus, if a body is acted upon by a compelling force in a given direction, it will move in that direction with a certain velocity; and, its motion may be represented by a straight line

the length of which is proportional to the velocity. If, at the same time, the body is acted upon by two impelling forces in different directions, it will obey both and move in a direction and with a velocity intermediate to that due to either force alone.

16. It is customary to term the forces acting on a body the *components,* and the resulting velocity and direction as the *resultant.*

17. It can be shown, by representing two components as the adjacent sides of a parallelogram, that a diagonal, passing through their points of intersection, will correctly represent the resultant. Thus, in figure 66, if a body at A be acted on at the same instant

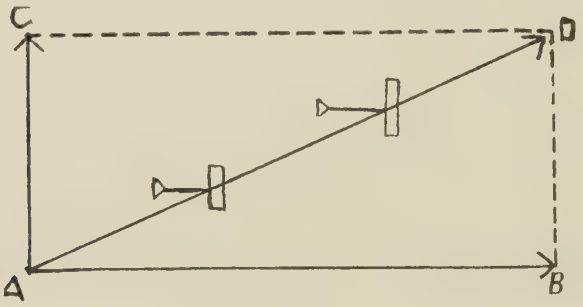


FIG. 66

by two impelling forces, represented in direction and velocity by the lines AB and AC, the combined effect of these forces, or the resultant, will be represented in direction and velocity by the diagonal AD of the parallelogram, whose adjacent sides are formed by the components AB and AC.

18. Applying the above explanation to an airplane drift problem, it is evident that if a plane at A attempts to fly from A to B, steering the straight course AB, and, during this time a wind is blowing from A to C, at the expiration of the time the plane will neither be at B nor C, but at D, having been moved along the diagonal AD by the combination of her own power and that of the wind. The result is exactly the same as if the plane had first

flown from A to B without being influenced by the wind, then stopped and been blown from B to D by the wind only. The line AD then actually represents the course and distance the plane made good.

19. When the course and speed of an airplane, together with the force and direction of the wind are known, it is evident the course and distance made good can be found either by construction or plain trigonometry. When the trigonomic solution is desired, the required data are found by solving the triangle, one side of which represents the velocity and direction of the wind, while the other represents the course and distance steered. In a like manner, when the direction and velocity of the wind are known, together with the *course and distance to be made good,* the course to steer may be found either mathematically or by construction. In practice, the mathematical solution of drift problems is seldom if ever used.

20. To illustrate the foregoing statements, several worked out examples will be given. Each example should be carefully studied and thoroughly understood before taking up the next.

21. *To find the course and distance made good when the course and distance flown and the force and direction of the wind are known.*

Example 1. A plane flew a distance of 75 miles on course 320° true in one hour. During the time of flight she was influenced by a N.N.E. wind with a velocity of 25 miles per hour. Find the course and distance made good.

Solution: Referring to figure 67, the line NS is drawn to represent the meridian, and graduate in any desired scale. From point A, near one end of the line, draw the line AB 320° (N.40°W.), 75 miles long. From the same point A draw the line AJ running S.S.W. = 202½° (S.22½°W.), 25 miles long. The two lines will now represent, respectively, the course and distance

flown and the set and drift due to wind. The parallelogram is now completed by drawing the lines BC parallel to AJ and JC parallel to AB. The diagonal AC is now drawn to represent the course and distance made good. Using the protractor, it will be

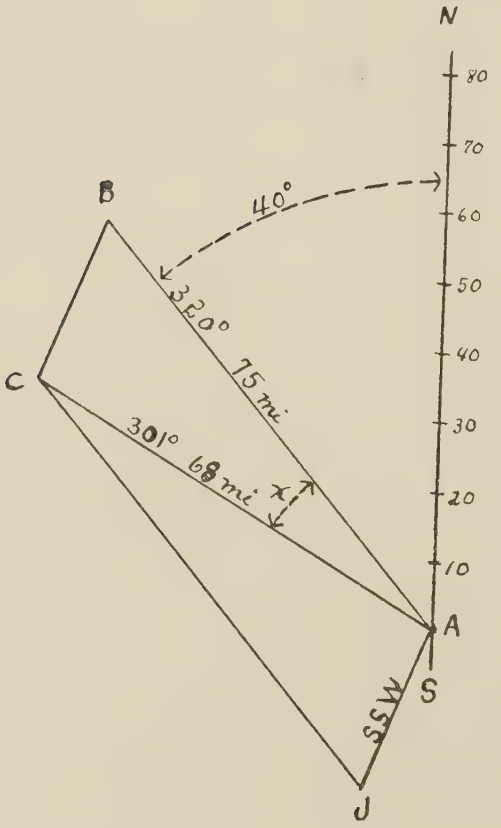


FIG. 67

found the course made good (angle NAC) was 301°, and the distance made good was 68 miles. Angle X, the angle between the course steered and the course made good, is the *angle of drift*.

Example 2. A plane flew a distance of 125 miles on course 45° in 1 hour and 15 minutes. During this time, she was influenced

by a N.W. wind with a velocity of 20 miles per hour. Find the course and distance made good.

Solution: Referring to figure 68, the line NS is drawn to represent the meridian and graduated in any desired scale. From point A draw the line AB, 45° and 125 miles long. From the same point A draw the line AJ, running SE, 25 miles. Line AB

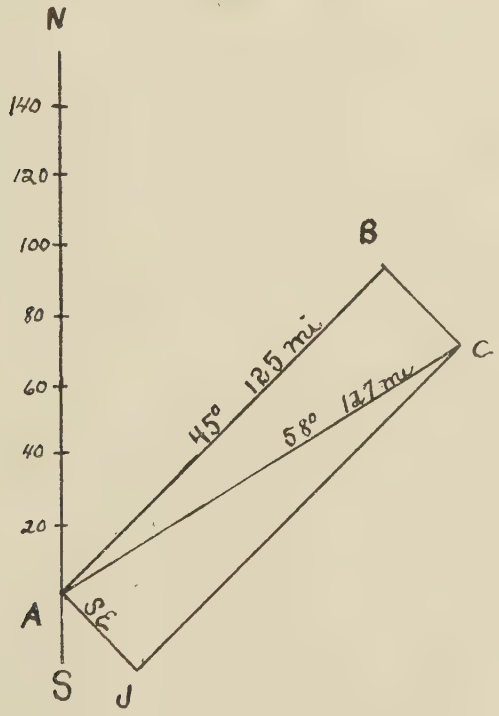


Fig. 68

will now represent the course and distance flown while line AJ will represent the set and drift due to wind. Lines BC and JC are now drawn to complete the parallelogram, and the diagonal AC to represent the course and distance made good. The course made good (angle NAC) is now measured and found to be 58°, and the distance was 127 miles.

22. *To find what course to steer when the course to be made good and the force and direction of the wind are known.*

Example 1. The course from field A to field B is 315°. Distance is 140 miles. The wind is blowing from N.E. with a velocity

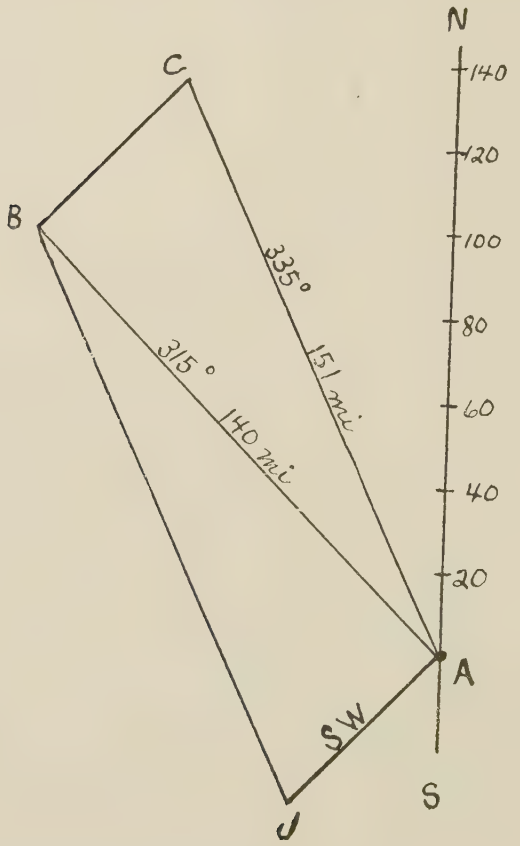


Fig. 69

of 25 miles an hour. Find the course to steer in a plane whose cruising speed is 70 miles per hour.

Solution: Referring to figure 69, draw line NS to represent the meridian and graduate according to any desired scale. From any point mark A and draw line AB running 315°, 140 miles

long. Draw line AJ running S.W. a distance of $2 \times 25 = 50$ miles. The line AB now represents the course and distance to be made good and line AJ represents the set and drift due to wind. The parallelogram is now completed by drawing the side BC

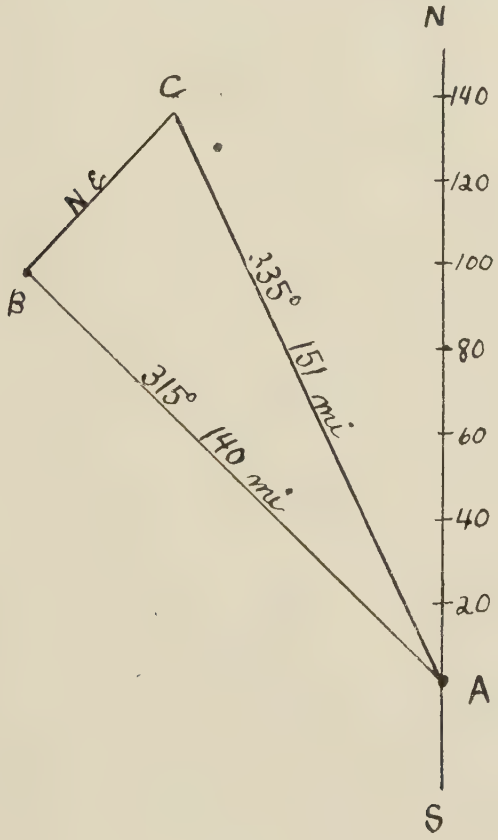


Fig. 70

parallel to JA, and side AC parallel to side BJ. With AB as a diagonal, the side AC will represent the course and distance to steer in order to reach field B. Measuring the angle NAC, the course is found to be 335°, and the distance through the air (length of AC) to be 151 miles. The difference between lines

AC and AB is the drift angle. As previously stated, the leeway is an allowance to counteract the effect of the wind; hence, the drift angle and leeway are always equal.

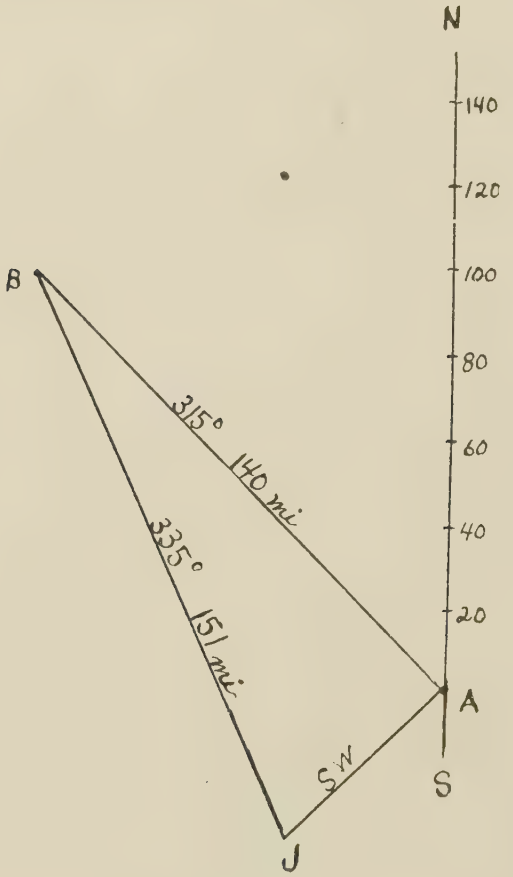


FIG. 71

23. In actual practice, the full parallelogram is seldom employed. Examining figure 69 closely we find sides AC and JB are equal in length and run in the same direction. Likewise, sides AJ and BC are equal and run in the same direction. It is apparent then, that exactly the same results may be obtained by use of the

triangle ABC, or AJB, either of which is commonly known as a *drift triangle*. To illustrate this, the last example will be solved by use of a triangle.

Solution: Referring to figure 70, draw line NS to represent the meridian and graduate to any desired scale. From any point on the line mark A, and draw line AB, running 315°, 140 miles. From point B draw line BC running N.E. (into the wind) 50 miles. The triangle is now completed by drawing the side AC which will represent the course and distance necessary to run in order to make good the line AB.

Second Solution: The same example will now be solved by using the triangle AJB. Referring to figure 71, the meridian and course line are drawn in the usual manner. Draw AJ, running S.W., 50 miles. Draw side BJ. The side BJ now represents the course and distance necessary to run in order to make good the line AB.

24. While both the above solutions give satisfactory results, the second method is recommended as it is the simplest and therefore the most practical. If possible, work should be done in units of one hour. By so doing the work is more accurate and conversion of wind, air speed, and ground speed, is not necessary. In the event that the point of destination is at a distance that will be covered in less than an hour, merely extend the track through and beyond it the necessary distance.

25. A few problems will now be solved by use of the drift triangle.

Example 1. The course from field A to field B is 345°. The distance is 120 miles. There is an east wind with a velocity of 30 miles per hour. Find the course to steer in a plane whose cruising speed is 80 miles per hour.

Solution: Referring to figure 72, draw line NS to represent the meridian. Locate point A near one end of the line NS, and

draw the line AB running 345° and 120 miles in length. Draw line AJ running west and 30 miles in length (one hour's wind). Now, with point J as a center and a radius equal to the air speed (80 miles), describe an arc which will cut the line AB at X. Draw the line JX which represents the course to steer in order

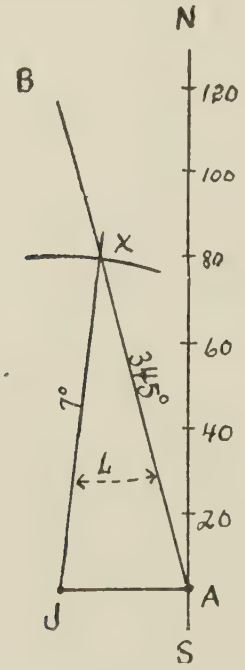


FIG. 72

to make good the line AB. Using the protractor, the angle L is measured and found to be 22°. The course to steer is therefore $345° + 22° = 7°$, which is the true course corrected for leeway. The distance AX is the ground speed which is 83½ miles per hour. Therefore, the plane cruising at 80 miles per hour air speed and steering 7° will, after one hour's run, be at X.

Example 2. The course from field A to field B is 210°. The distance is 110 miles. A west wind is blowing with a velocity of

35 miles per hour. Find the leeway to allow and the ground speed of a plane with a cruising speed of 90 miles per hour.

Solution: Referring to figure 73, draw line NS to represent the meridian. Locate point A and draw the line AB running 210°, 110 miles in length. Draw the line AJ running east and 35 miles in length. With point J as a center and a radius equal to the air speed (90 miles), describe an arc which will cut the

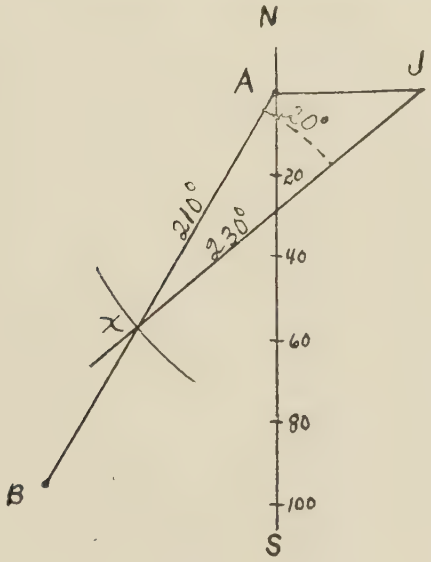


FIG. 73

line AB at X. Draw the line JX which represents the course to steer. Using the protractor the leeway is found to be 20° right. The distance AX is now measured and found to be 67 miles.

Example 3. The true course from Chicago to Indianapolis is 149°. There is S.S.W. wind blowing with a velocity of 40 miles per hour. Find the leeway and ground speed of a plane with a cruising speed of 100 miles per hour.

Solution: Referring to figure 74, draw line NS to represent the meridian. Locate point A and draw the line AB running

149° and of indefinite length. Draw the line AJ running 22½° and 40 miles in length. With point J as a center and a radius equal to the air speed (100 miles), describe an arc which will cut the line AB at point X. Draw the line JX. With a protractor angle L is measured and the leeway is found to be 19°.

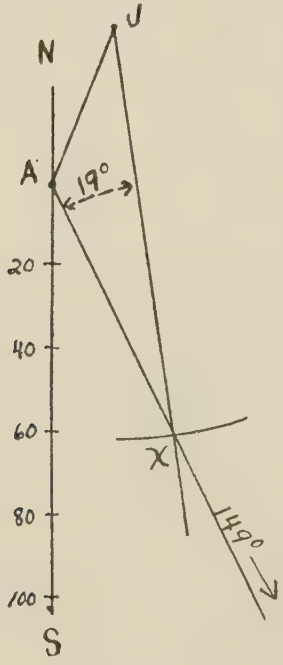


FIG. 74

The distance AX is measured and the ground speed found to be 68 miles per hour.

26. In practice, it is customary to work drift problems on the map in use. The true meridian is used instead of the NS line, and the course line, as plotted on the map, is the line AB. The scale of miles shown is of course used for the measurement of lines which are drawn exactly as in the above examples.

27. The leeway found before taking off may or may not be correct for the entire flight. Should the wind change either in force

or direction during the flight, the leeway must be corrected accordingly. Various instruments have therefore been devised for maintaining the correct leeway. As previously stated, the angle of drift and leeway are equal, hence any instrument that can be used to measure the angle of drift will at once give the correct leeway.

28. In figure 75, a plane bound from A to B is steering 340° (true) to make good 360° (true), thus allowing 20° leeway. It is evident that objects on the ground directly below the plane will, after a few second's run, bear 20° on the port quarter if the leeway is correct. For example, assume the ship to have passed directly over some well defined object at X. The angle SOX should then be 20°. If the drift angle (SOX) is more or less than 20°, the leeway is not correct and the plane is not making good the line AB. It will be noted that the reverse bearing of X will give *the course being made good.*

29. Perhaps the simplest form of instrument for measuring the drift angle is the pelorus, mounted so bearings may be taken on both quarters. In figure 75, the zero mark of the pelorus bearing plate could be set for the planes heading thus having the 0° — 180° line parallel to the ship's fore-and-aft line. Object X should then bear 200° (180° + leeway), or 20° on the port quarter. Another method is to set the pelorus for the *course to be made good* and note the reverse bearing of objects which are passed over. When the reverse bearing and course to be made good differ, the leeway must be corrected.

30. In figure 76, a plane bound from A to B is steering 350° (true), to make good course 5° (true), which is an allowance of 15° for a west wind. Desiring to check the leeway, a bearing is taken of the building X, which was passed directly over a few seconds before. Bearing was found to be 185°. Reversing this

gives 5°, or the course to be made good. Evidently the leeway is correct.

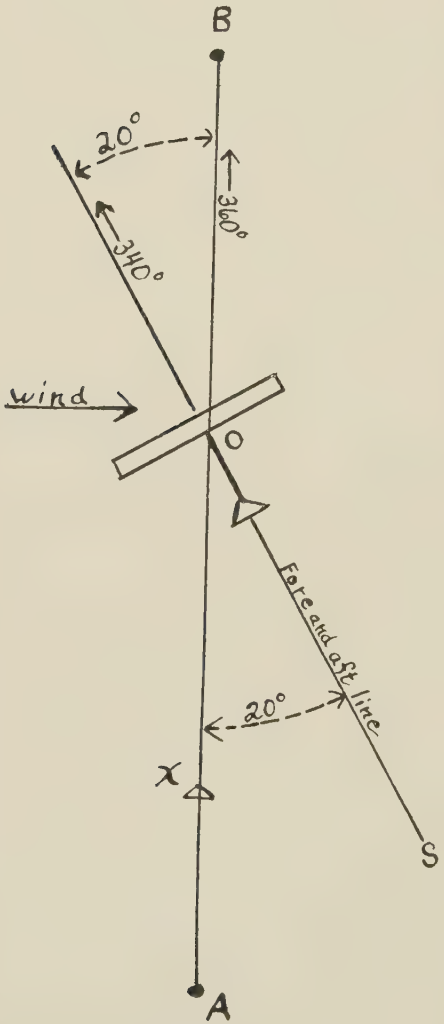


Fig. 75

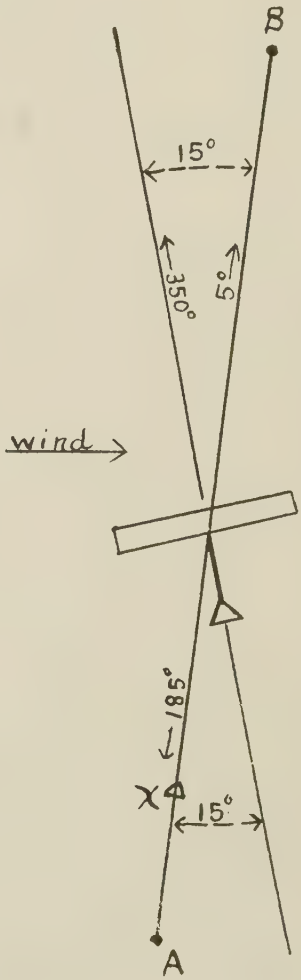
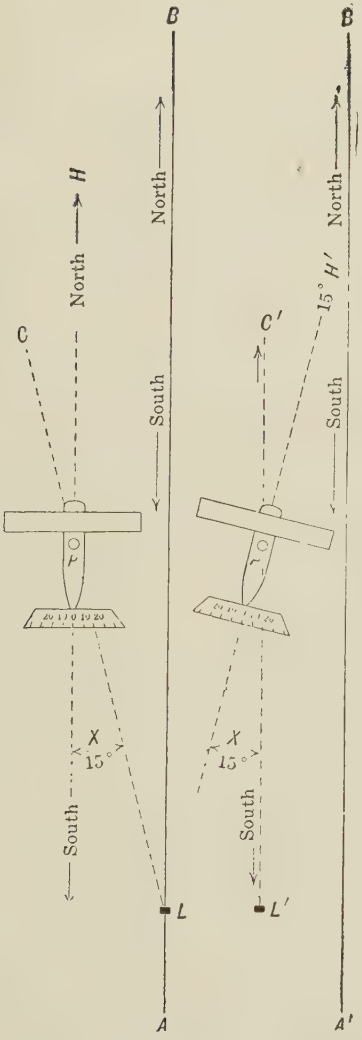


Fig. 76

31. The relative bearing, figure 76, is found by reversing the heading of the plane and taking the difference between this reversed heading and the bearing:



Explanation

Left: plane is following line AB which runs true north. Plane is steering true north which allows no leeway.

H = True course being steered

LPC = True course being made good, which is 15° left of the line AB

X = Angle between course and line to L = 15° leeway.

Right: the course has been corrected for leeway and a smoke box dropped at L'.

H' = True course being steered, which is 15° right of line AB.

L'P'C' is course being made good = North true.

As long as the plane steers 15° true, and X remains 15°, true north will be made good.

FIG. 77

Solution:	Course	= 350°
		180°
	Reverse course	= 170°
	Bearing	= 185°
	Relative bearing	= 15°

Thus, the relative bearing is 15° on the port quarter, showing the leeway to be correct.

32. If, on taking the bearing in figure 76, the angle of drift is found to be 20° instead of 15°, it is apparent that the ship is being set to the eastward of the line AB. Sufficient leeway is not being allowed and an increase of 5° must be made at once. This is done by changing the course to 345° true. The leeway, relative bearing and drift angle will now be 20°.

33. An excellent method of observing the drift angle (correcting leeway) and one that is frequently employed on long water flights where landmarks are not available, is to graduate the stabilizer into degrees so the eye of the observer in the cockpit will be the center of the circle. See figure 77.

A plane, running the line AB, wishing to measure its drift angle (leeway), drops a smoke box at L. After a run of a mile or two, the observer looks over the stern and notes the relative bearing. X is then the drift angle (leeway).

34. An instrument designed for measuring the drift angle, and frequently found on well-equipped planes, is the *Pioneer Speed and Drift Indicator*. See figure 78. To obtain the drift angle with the Pioneer Speed and Drift Indicator, the navigator sights through the eye piece at the drift wire and the ground below. The vane is now moved in or out so that objects on the ground appear to travel along the drift wire. The drift wire is now in line with the course being made good, and the drift angle (leeway) can be read directly from the graduated arc.

35. To obtain the ground speed, the vane is left in position corresponding to the drift angle and the slider is moved along the vane until the crosswire is at the figure corresponding to the altitude above the ground *being flown over*. This may differ

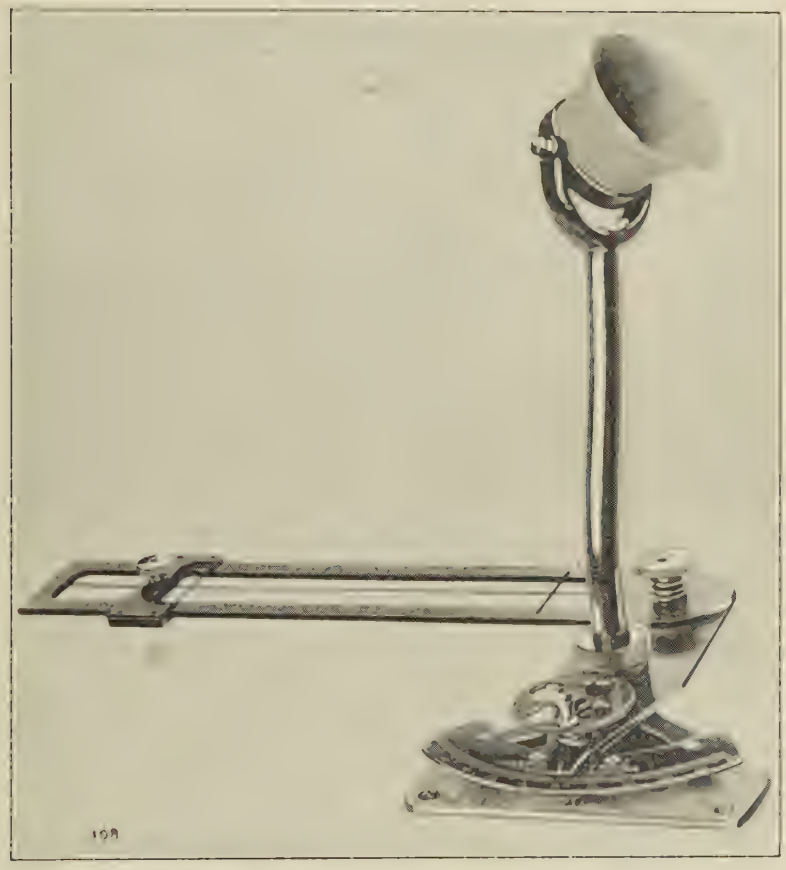


FIG. 78

somewhat from the altitude referred to the point of departure and, if so, must be corrected accordingly.

36. With a watch, the time of passage for an object on the ground from one crosswire to the next is noted. On the side of the vane

is a scale showing the actual distance seen on the ground between the two wires. Using this distance and the time required to run it as arguments, the speed may be found by simple arithmetic.

Example: A plane flying at an altitude of 4,000 feet, having obtained her drift angle by the drift indicator, moves the slider along the vane and sets the crosswire at figure 4, which is on the scale marked "four-tenths mile for altitude in thousand feet." Time of passage of an object on the ground between the crosswires was 12 seconds. As the time of passage was 12 seconds for $\frac{4}{10}$ miles, $\frac{1}{10}$ miles would be 3 seconds, and 1 mile would be 30 seconds, or 120 miles per hour.

37. A very handy method of correcting leeway when flying alone is by use of the "Course Error Table," given in the back of the book. Before taking off the original leeway is calculated as near as possible and prominent landmarks noted at regular intervals, together with the time they should be made. During the flight, the pilot checks his leeway and speed on how he makes these selected points, increasing or decreasing the leeway as necessary.

38. The "Course Error Table" is entered in the left-hand column with the distance run. To the right of the distance, and on the same horizontal line, is the *distance off*. Heading this column is the necessary correction, which is applied to the left or right depending on which side of the selected landmark the plane has drifted.

Example 1: A plane is bound from New York City to Auburn, N. Y., steering 339°, which includes 13° leeway for an east wind. The course, as plotted, passes exactly over Port Jervis, which is 56 miles from New York. After running the required time, the town is sighted about 6 miles to the left. What was the error in leeway and what is the correct course?

Solution: Referring to "Course Error Table," in the back the

book, it is found that for a distance of between 50 and 60 miles, a drift of approximately 6 miles will be in the 6° column. $339° - 6° = 333°$, which will be the required course. It will be necessary, however, to run to the left for a few minutes to get back on the original line, as the plane is now 6 miles to the right of the course shown on the chart, and running parallel.

Example 2: A plane is bound from Boston, Massachusetts, to Philadelphia, Pennsylvania, steering 255°, which includes 18° leeway for a north wind. The course, as plotted, passes exactly over the city of New Haven, a distance of 120 miles from Boston. After running the required time, the city is sighted well to the left, an estimated distance of 12 miles. What was the error in leeway and what is the correct course?

Solution: Referring to the "Course Error Table," in back of this book, under 100 miles will be found a drift of 10.6 miles in the 6° column, and under 20 miles, a drift of 2.2 miles, making a total drift of 12.8 miles for an error of 6°, which is the amount the leeway was over-estimated. $255° - 6° = 249°$, which will be the required course.

39. While the use of the "Course Error Table" will not give mathematically accurate results, it is quite close enough for practical purposes. If the distances from the chosen landmarks are estimated within reasonable limits, no difficulty will be experienced following the desired course.

40. The following worked out examples should be studied carefully and every step of the work understood before attempting to solve the examples for practice given at the end of this chapter. In practice, many of the examples could and would be worked mentally but the beginner should not attempt this. Until proficiency in compass work is attained, always lay out a diagram and enter all the known data before starting the mathematical work.

41. The following rules should be memorized:

Rule I. *To convert a true course into a compass course, subtract easterly variation and deviation and add westerly variation and deviation. Apply leeway into the wind.*

Rule II. *To convert a compass course into a true course, add easterly deviation and variation and subtract westerly deviation and variation. Allow leeway with the wind.*

In connection with the above rules, the following jingle will serve well as a memory aid:

When true to compass is the test,
East is least and west is best.
But if compass must be true,
East will gain and west will lose.

EXAMPLES FOR STUDY

Example 1. The true course, as found on the map, between A field and B field is 22°. Variation, 25° E. Deviation, 8° W. Leeway, 11°. Wind, northwest. What is the compass course?

Solution:

True course	= 22°
Variation	= 25° E.
Magnetic course	= 357°
Deviation	= 8° W.
	5°
Leeway	= 11°
Compass course	= 354° = ans.

Example 2. The true course from field A to field B is 172°. Variation, 2° E. Deviation, 13° E. Leeway, 20°. Wind, east. What is the compass course?

Solution:

True course	= 172°
Variation	= 2° E.
Magnetic course	= 170°
Deviation	= 13° E.
	157°
Leeway	= 20°
Compass course	= 137° = ans.

Example 3. True course between field A and field B is 352°. Variation, 17° W. Deviation, 3° E. Wind, easterly. Leeway, 5°. Find the compass course.

Solution:

True course	= 352°
Variation	= 17° W.
Magnetic courses	= 9°
Deviation	= 3° E.
	6°
Leeway	= 5°
Compass course	= 11° = ans.

Example 4. True course from field A to field B is 40°. Variation, 10° E. Deviation, 8° E. Leeway, 15°. Wind, North. What is the compass course?

Solution:

True course	= 40°
Variation	= 10° E.
Magnetic courses	= 30°
Deviation	= 8° E.
	22°
Leeway	= 15°
Compass course	= 7° = ans.

Example 5. A plane flying over strange country is forced down by fog. To locate the point of landing, the pilot consults his flight notes and finds the compass course has been 305°, deviation 3° W., and variation 5° W. Leeway of 8° for a north wind was allowed. What was the true course?

Solution:

Steering course	$= 305°$
Leeway	$= 8°$
Compass course	$= 297°$
Deviation	$= 3°$ W.
Magnetic course	$= 294°$
Variation	$= 5°$ W.
True course	$= 289° =$ ans.

Example 6. A plane flew on course 354° by compass, variation 25° east, deviation 8° west. 11° leeway for a northwest wind. What was the true course?

Solution:

Steering course	$= 354°$
Leeway	$= 11°$
Compass course	$= 365°$ (or $5°$)
Deviation	$= 8°$ W.
Magnetic course	$= 357°$
Variation	$= 25°$ E.
True course	$= 382° = 22° =$ ans.

EXAMPLES FOR PRACTICE

Example 1. The true course is 30°. Variation 28° W. Deviation 6° E. Leeway 15°. Wind northwest. What is the compass course?

Answer—37°.

Example 2. True course is 350° Variation 4° E. Deviation 14° W. Leeway 10°. Wind, west. What is the compass course?

Answer—350°.

Example 3. The true course is 312°. Variation 5° E. Deviation 19° W. Wind, south. Leeway 10°. What is the compass course?

Answer—316°.

Example 4. The true course is 172°. Variation 2° E. Deviation 13° E. Leeway 5°. Wind, south. What is the compass course?

Answer—162°.

Example 5. The true course is 133°. Variation 28° W. Deviation 3° E. Leeway 5°. Wind, southwest. What is the compass course?

Answer—163°.

Example 6. The true course is 189°. Variation 10° E. Deviation 5° W. Leeway 4°. Wind, east. What is the compass course?

Answer—180°.

Example 7. The true course is 227°. Variation 10° E. Deviation 3° W. Leeway 5°. Wind, northwest. What is the compass course?

Answer—225°.

Example 8. The true course is 6°. Variation 9° E. Deviation 7° W. Leeway 4°. Wind, west. What is the compass course?

Answer—0° or North.

Example 9. The true course is 349°. Variation, 9° E. Deviation 3° E. Leeway 5°. Wind, southwest. What is the compass course?

Answer—332°.

Example 10. True course is 30°. Variation 15°W. Deviation, according to deviation card. What is the compass course?

Answer—50°.

NOTE: In the following examples, deviations will be taken from table IV. The true course is first converted into a magnetic course. The table is entered with the magnetic course to the nearest tabulated value and deviation found.

TABLE IV

DEVIATION CARD

For magnetic compass No. 21784 of Waco plane, adjusted at Municipal Field, Tampa, Florida.

DATE: June 15, 1927 E. A. RICH, *Pilot.*

Head by Compass	Deviation	Head by Compass	Deviation
0°	2° E.	180°	1° W.
15°	0°	195°	0°
30°	3° W.	210°	2° E.
45°	5° W.	225°	3° E.
60°	7° W.	240°	5° E.
75°	8° W.	255°	6° E.
90°	10° W.	270°	8° E.
105°	8° W.	285°	7° E.
120°	6° W.	300°	6° E.
135°	4° W.	315°	4° E.
150°	3° W.	330°	3° E.
165°	2° W.	345°	3° E.

CAPTAIN L. A. YANCEY, *Adjuster,*
715 Continental Bldg., Baltimore, Md.

Example 11. True course is 225°. Variation is 15° W. Deviation, according to deviation card. What is the compass course?

Answer—235°.

Example 12. True course is 322°. Variation 8° E. Deviation, according to deviation card. What is the compass course?

Answer—310°.

Example 13. True course is 97°. Variation 8° E. Deviation, according to deviation card. What is the compass course?

Answer—99°.

Example 14. A plane, bound from New York City for Auburn, New York, found the true course from the chart to be 319°. According to the variation chart, the mean variation is 10°W. A drift triangle was constructed and an allowance of 13° was found necessary to compensate for an east wind. Deviation according to card. What is the course to steer?

Answer—339°.

Example 15. A plane bound from Mineola, Long Island, to Providence, Rhode Island, finds the true course from the chart to be 56°. Variation, according to the variation chart, is 12° W. Deviation according to card. A fresh north wind is blowing and by construction of a drift triangle, leeway of 15° was found necessary. What is the course to steer?

Answer—61°.

Example 16. In the above example, the distance from Mineola to Providence was found to be 135 miles. After having run the required 135 miles on course 61°, the pilot sights the city of Providence about 9 miles on the starboard beam. What (a) was the error in the course, and (b) what should he have been steering?

Answer—(a) 4°; (b) 65°.

CHAPTER VIII

CROSS COUNTRY WORK

1. A great many pilots, when starting a cross country flight, hurry into the air and start the trip without the proper preliminary study of the country over which they expect to fly. Such men often lose themselves and meet with serious mishaps. It is often said, and correctly so, that careful preparation for a cross country flight is half the flight finished.

2. Perhaps the most important single item in successful long distance flying is suitable maps A general map of the entire country should first be consulted, and the route roughly chosen. A Rand McNally railroad location map of the United States and Canada is ideal for this purpose. Similar general maps may be obtained covering any part of the world, or a good topographical map of an entire country may be used for the double purpose of planning the general route and a study of the elevations.

3. Having obtained a suitable general map on which the entire journey may be shown on one sheet, the point of departure and point of destination should be connected with a light pencil line. This line will represent the general route to be followed and is the shortest distance between the two places. Study the line carefully and see if this direct route is the logical one to follow. Usually a slight deviation will simplify the work considerably as well as increase the factor of safety. For example, the shortest route between Denver, Colorado, and Spokane, Washington, would be over mountains from 10,000 to 12,000 feet high, and a forced landing, over most of the route, would mean certain disaster. A close examination of the topographical map shows that

by skirting the mountains to the northward extreme altitudes may be avoided, and the number of towns indicate possible help, if needed, as well as making excellent landmarks. Again, a plane following the shortest route between Provincetown, Massachusetts, and Atlantic City, New Jersey, would have to cross a long stretch of the sea, which by all rules of common sense and reason should be avoided in favor of the more practical route by way of New York City.

4. Having decided on the general route from a study of the small scale map, note the states over which flight is to be made and obtain maps of the proper scale for each. Transfer the route from the small scale map to the several state maps. This is easily done by noting where the line intersects the borders of each state. The state maps should now be studied and the route varied slightly as found necessary to increase safety and simplify navigation. For example, the shortest route from Pittsburgh to Kansas City, would pass about 20 miles north of Columbus, 10 miles north of Indianapolis and 15 or 20 miles south of Springfield, Illinois. In plotting the route for this flight the straight line should be cut up into a series of legs, so to speak, and each of the above cities passed over. This would necessitate several small changes of course in running from one city to the next, but on the other hand would eliminate the possibility of becoming confused. The additional distance is not worth considering and availability of airports makes the route ideal from a safety standpoint.

5. Having decided on the exact route to be followed, plot the courses by connecting the various cities or prominent landmarks along the route with a light pencil line. In the flight from Pittsburgh to Kansas City, the first course would be from Pittsburgh to Columbus, the second from Columbus to Indianapolis, etc. Study the country for 15 or 20 miles on each side of the

course line. Select such prominent landmarks as cities, towns, rivers, lakes, railroads and note how far they are from the point of destination and the probable time they will be passed over, or if the course does not lead directly over them, on which side they will pass and how far off.

6. Particular attention must be paid to the height of the land to be flown over, especially in mountainous regions. It must be remembered that the altimeter shows the *height above the ground at the point of departure only*. See figure 79. The altitude above sea level at the point of departure should be accurately known,

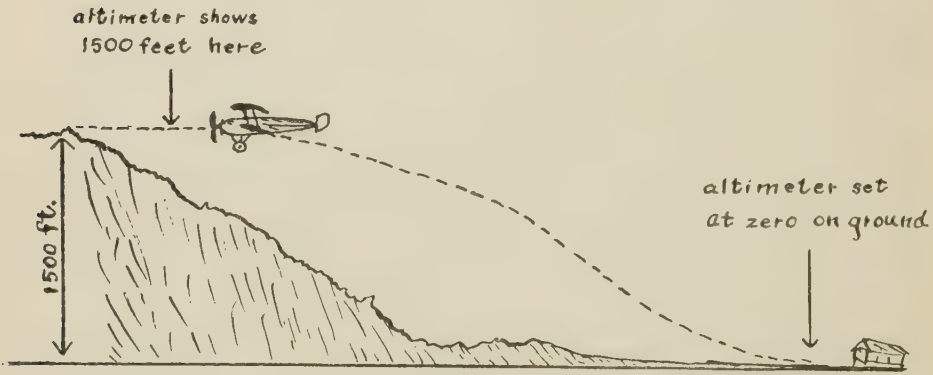


FIG. 79

and the altimeter set for this altitude. The difference between the altimeter reading and heights shown on the map will then give the height above the ground when in flight. The city of Plattsburg, N. Y., is approximately 1,000 feet above sea level. A plane taking off from that city would set the altimeter at 1,000 feet (assuming this to be the correct altitude). The pilot is now in a position to compare heights of the surrounding mountains, as shown by the map, with the altimeter direct.

7. From a study of the maps a good mental picture of the country may be formed. Characteristic landmarks should be looked for, such as a town in the forks of a river; a railroad bridge cross-

ing a river near a bend; etc. The map is really a picture of the ground being flown over, and the more it is studied the more certain the pilot is not to get lost.

8. Each course is now measured and corrected for variation and deviation, and the resulting compass course written on the map along the course line. The initial course should also be corrected for leeway and the ground speed calculated. It is also a good plan to place a cross mark along the course line at intervals of 10 or 15 miles as an aid to measuring distance while in the air. Too much care cannot be exercised in measuring and correcting courses. Although it is possible to fly from place to place with the aid of a map alone, the pilot must not forget that the compass is a more valuable friend than even the map. If the course has been properly measured, corrected and carefully steered, he can arrive at the point of destination without the use of the map at all. It is possible for a map to be blown away, or for it to be difficult to read owing to bumps. The very great area of country that can be seen from an airplane makes it an easy matter to strike the point of destination even after a flight of several hundred miles by compass.

9. As a memory aid while in flight, and to eliminate the constant use of the map, a *time table* may be made up showing the time the selected landmarks should be made. By setting the clock at 12:00 when taking off the time table will replace the map to a great extent. Figure 80 shows such a table covering a flight of 300 miles.

10. A full sized map is sometimes difficult to handle in a plane, especially if it be an open job, or the pilot be flying alone. A convenient way to overcome this difficulty is to cut the map in strips, leaving four or five inches on either side of the course line. The strips may be cut into convenient lengths and numbered in the sequence in which they will be used. In this way the pilot

Time	Distance	Course	Landmark
0	...	270°	
15min.	20	350°	Hudson River. Keep on right.
1h. 5min.	86	....	Large town. Field 1 mile north.
1h. 25min.	113	....	River turns west. Large town. Mountains slightly to right.
1h. 55min.	153	300°	Large lake. Town on S.W. shore. Follow west bank for 6 miles.
2h. 5min.	170	....	R.R. bridge ¼ mile right.
2h. 20min.	190	....	River from N.W. and one from west join, flow S. as one. Small town in fork.
2h. 40min.	218	320°	3 small lakes 1 mile right.
2h. 50min.	231	....	1 small lake. Pass over.
3h. 20min.	271	....	Large town. R.R.'s running N.W., W., S.E., and E. Field 1 mile south.
3h. 30min.	284	....	Several stone buildings. State prison.
3h. 43min.	300	....	Field 3 miles south of town. Look for large white dome.

FIG. 80

has only a small section of the map to handle at one time. There are several good types of map carriers on the market in which a strip map may be rolled on one roller before taking off, and while in the air slowly rolled on to another, exposing a flat section of the map about 12 inches long in the operation. If a map carrier of this type be at hand, any number of strips may be pasted end on end, and thus eliminate the necessity of hunting for the next sheet.

11. After taking off, the engine is brought to cruising speed and the plane settled on the compass course. The landmarks in the time table should be made exactly on time and on the correct retative bearing. If they are not, the strength or direction of the wind, possibly both, were not estimated accurately and must be corrected. The course error table is a convenient way of doing this.

12. While in flight steer the compass course carefully, and check off the landmarks as passed, and be sure they are passed as intended. It is the only sure way of keeping exactly on the course to be made good.

13. Generally speaking, from 2,000 feet to 3,000 feet *above the ground* is a suitable flying altitude. This may be modified greatly by existing conditions, such as clouds, visibility or rough country. If a range of 3,500 foot hills must be crossed, the minimum altitude while in their vicinity, would be 5,000 to 6,000 feet. The plane must be kept low enough to enable the pilot to spot emergency landing fields, keep track of the wind direction and recognize landmarks. On the other hand, it must be high enough to glide to safety in an emergency.

INSTRUMENT FLYING

14. There are many difficulties such as rain, snow or fog which the cross country flyer must face. He may be nearing his des-

tination, or running short of fuel, and be above a solid bank of thick clouds. When the ground is lost sight of, and the horizon disappears, there is grave danger of the best pilots getting into trouble. This is particularly true when flying over long stretches of water at night, where, even in clear weather the most experienced are unable to maintain balance without the aid of instruments especially designed for that purpose.

15. It is a well established fact that as long as a pilot can see even a single fixed object such as a light spot in fog or cloud bank, a faint horizon, or an occasional glimpse of the ground, flight with a fair degree of safety is possible. However, should all objects outside the plane be blotted out, as is the case in heavy fog, thick clouds, or long night water flight, *it is a physical impossibility,* without special equipment, to continue normal flight for any appreciable length of time. The pilot's so called normal "flying sense" not only may be entirely wrong, but it may be exactly opposite what it would have been if objects outside the plane were visible.

16. As explained in a previous section, the compass is a perfectly reliable instrument except when turning, then, as already explained, the vertical component of the earth's magnetic force acts upon the inclined card and tends to draw the north point downward (in northern latitudes). The compass card and the plane may be turning at the same time and at the same speed and therefore, to the pilot depending on the compass alone, neither will appear to be turning. The compass card may turn faster than the plane, causing the pilot to believe he is turning in the *opposite direction to the actual turn.*

17. In clear weather the pilot can and does use some fixed reference point in maintaining level flight. Under these conditions, constant and reliable compass readings are obtained. Should bumpy air cause a low wing, the compass will oscillate somewhat,

but before the card has begun to swing the wing is brought up, thus returning the compass card to its normal position. When flying in fog or thick weather, conditions are much different. The pilot *would attempt* to keep the wings level with the lateral bubble, and the speed constant with the air-speed indicator and longitudinal liquid level, while he maintained straight flight by the compass. But, should the ship turn slightly the inside wing will become low, and as the compass begins to swing *the ship is put into a perfectly banked turn by keeping on the course, as indicated by the compass, and keeping the lateral bubble centered.* The result is that the plane *appears and feels to be level and in straight flight, while it is actually turning.* As the turn progresses the compass card becomes erratic and appears to spin, leaving the pilot without a directional guide. The pilot attempts to keep the ship in what he believes to be normal flying altitude, *but what is actually a turn,* by his so-called "flying sense" aided by the lateral bubble, longitudinal level, and air-speed indication. The usual result is a tight spiral that generally leads into a spin.

18. As explained above, a compass, by itself, is of very little value in conditions of blind flight, as it will indicate correctly only during straight level flying, or on very wide flat turns. If however, the compass be used in conjunction with some instrument that will detect and show the turning movement, the danger of starting a turn unconsciously will be eliminated, and the principal hazard of poor visibility will be overcome. Figure 81 shows a *turn and bank indicator.* This instrument was developed to enable a plane to maintain straight flight under conditions of poor visibility. As long as the plane remains headed in the same direction the pointer on the dial of the turn indicator will stay in the center. Any variation from a straight course will be shown by the pointer moving to the right or left. It will return to the center when straight flight is resumed. Thus, assume a plane flying on

course 350° desires to change course to west. As long as the head is kept on 350° the pointer remains centered, but when the rudder is put over and the plane starts swinging toward west (left), the pointer moves to the left and stays there until straight flight is again resumed. As soon as the ship has steadied on west the pointer returns to center.

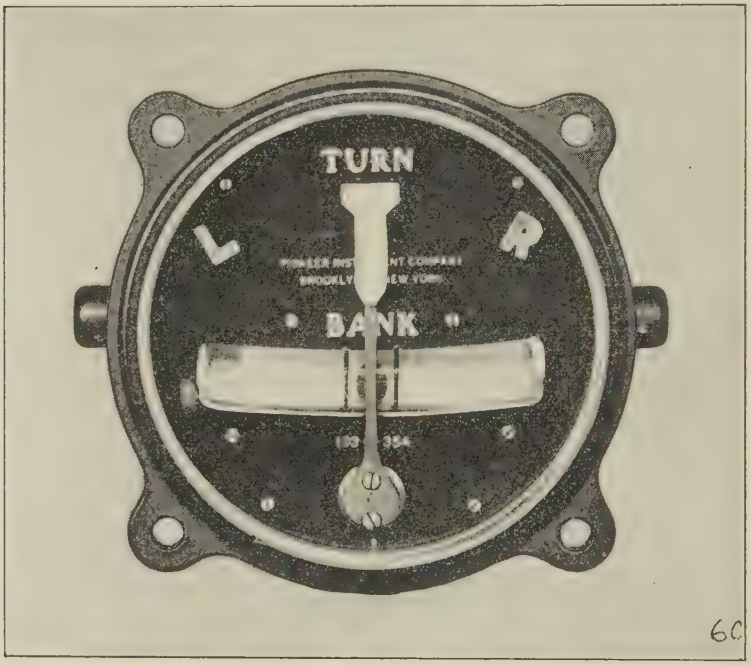


FIG. 81

19. The sensitive element of the turn indicator is a small air-driven gyroscope rotating about a horizontal athwartship axis, and so mounted in a cradle that the torque devolved by any movement about the vertical axis deflects a spring, the amount of deflection being indicated by the pointer on the dial. The gyroscope is operated by a vacuum secured by use of a venturi tube, which should be mounted in the slipstream, thus assuring opera-

tion when taking off. Built into the dial of the turn indicator is a lateral level, or bank indicator. By using the bank indicator in conjunction with the turn indicator, lateral level and straight flight may be maintained. By using the turn and bank indicator in conjunction with the compass, straight flight *in any desired direction* may be maintained.

20. Flying blind *in smooth air* is a comparatively simple matter, though a certain amount of practice is necessary. The compass course is steered and the ship kept level in the usual manner, but *the turn and bank indicator must be watched very carefully.* In bumpy air the pilot must concentrate on the turn and bank indicator, using the compass only when flying straight and level and forgetting it completely at the first sign of a low wing or a turn.

RADIO DIRECTION FINDING

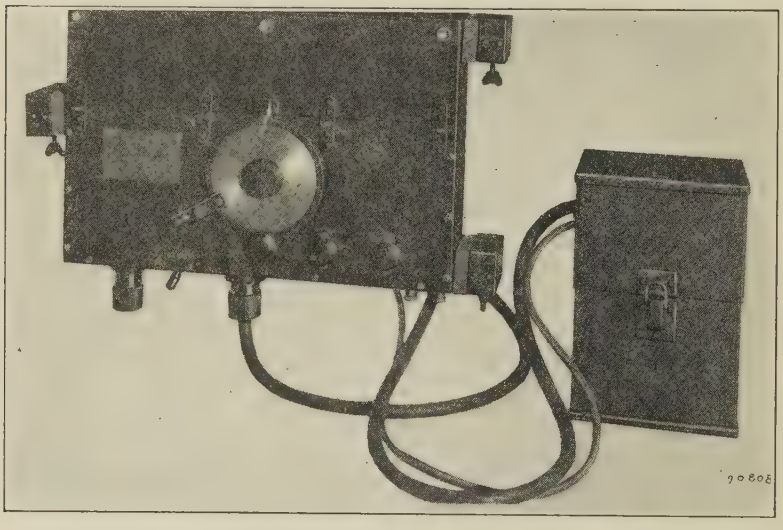
21. The *radio compass* is an invention growing out of the war, and was originally developed to detect the position of enemy fighting craft when they made use of their radio equipment. The United States Bureau of Standards is credited with having discovered the principle of radio compass, while the Navy Department worked out its practical application.

22. While experimenting with electromagnetic waves it was found that when waves sent out by a radio station cut a coil of wire at right angles, current was made to flow through the coil, but when the coil was turned parallel to the wave, no current flowed. With this principle to work on the Navy Department began extensive experiments in 1916, and eventually developed an efficient receiving antenna in the form of a coil, or loop.

23. The direction finding element of the radio compass is the coil or loop antenna. Generally speaking it consists of a single wire wound around a five- or six-foot square frame. The coil is

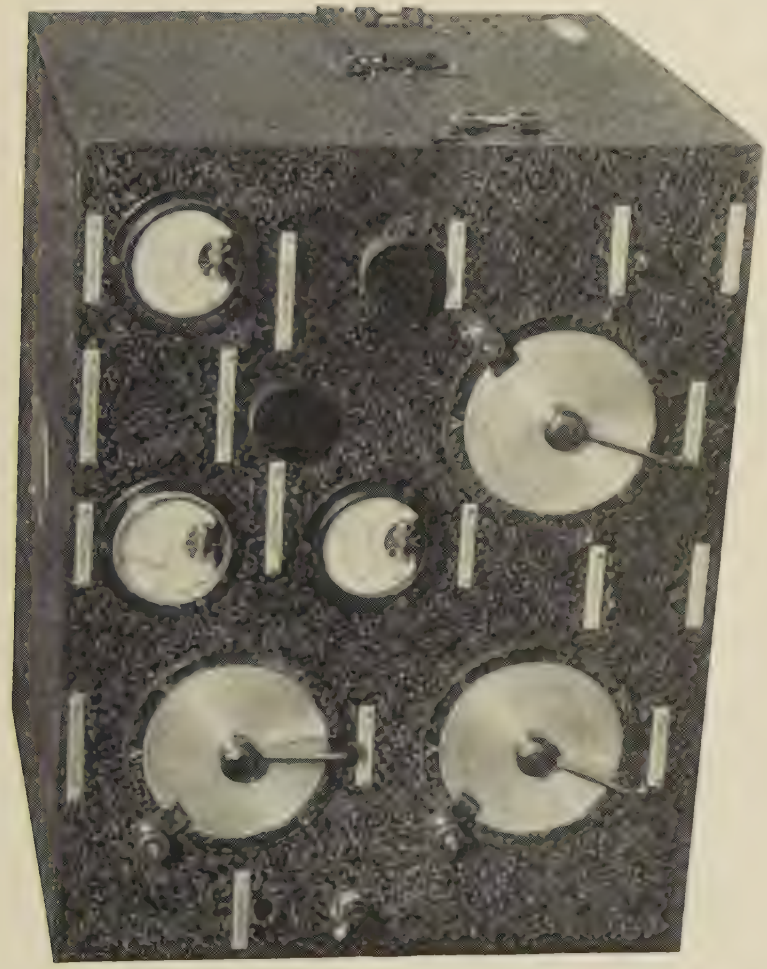
LIBRARY
College of St. Scholastica

attached to the upper end of a vertical shaft in such a manner that it may be revolved. The ends of the wire lead down and are attached to the receiving set. Attached to the lower end of the shaft, in the operating room, is a wheel which is used to turn the coil. Just below the turning wheel and attached to the shaft, is a direction pointer which revolves with the shaft. Directly under the pointer is a stationary compass dial graduated into 360° with the 0°-180° line in the plain of the true meridian.



Special Aircraft Transmitter Built for the New York-to-Rome Flight by the Radio Corporation of America (Courtesy Radio Corp. of America).

24. When a sending station wishes to obtain its bearing from a radio compass station, a prearranged signal is sent for about a minute. As the signal comes in the radio compass operator slowly revolves the coil antenna and listens to the signals. When the coil is facing the incoming wave no signal is heard. As the operator revolves the coil, signals of increasing strength are received until a maximum point is reached, and as the coil continues to revolve, the signals decrease in strength until a second



Special Aircraft Receiver Built for New York-to-Rome Flight by the Radio Corporation of America (Courtesy Radio Corp. of America)

silent spot is found when the coil is again facing the incoming wave. As it is easier to determine the silent points than the point of maximum strength, the dial and pointer are arranged to indicate the bearing of the sending station when no signals are heard.

25. Radio compass stations are usually arranged in groups of three, consisting of a master and two sub-stations, some distance from each other. When a position is desired the sending station calls the master radio compass station and gives the required signal for about a minute. As the signal is being sent all three stations obtain bearings which are later telephoned to the master station. In marine practice the bearings thus obtained are transmitted by the master station to the station requesting them, where they are plotted on the chart and the position found by the navigator himself. In European aviation the practice is for the bearings to be plotted by the master station and the position transmitted to the requesting station. The radio compass has been but little used in American aviation.

RADIO BEACON

26. A number of demonstrations have recently been given of the radio beacon system developed by the Bureau of Standards for aircraft. The system is sufficiently perfected at present for routine use, and is being installed on a number of the principal airways throughout the country. The only equipment necessary to enable a plane to make use of the system is a small receiving set fitted with an indicator.

27. As originally installed, when a plane flew on a predetermined line leading directly to or away from the sending beacon, the Morse code letter R (. — .) would be heard continually. Should the ship get off the line to the right the letter N (— .) would be heard; if to the left, the letter A (. —). Recently an indicator

has been brought out which does away with the usual ear phones. It is very simple and practical and is plugged into the receiving set, in place of the ear phones.

28. The most successful form of visual indicator, and the one that will probably be adopted for general use, consists of two vibrating steel reeds, the tips of which are white with a black background placed behind them. When beacon signals are being received, the two reeds vibrate and the white tips against the black background appear as a vertical white line. It is only necessary for the pilot to watch the two white lines produced by the vibrating reeds, and keep them of equal length, to stay on his course. If the left line becomes shorter the ship is falling off to the left, and vice versa.

29. While the radio beacon can be used with any receiving set which operates at the required frequencies by merely replacing the ear phones by the indicator unit, there are many conditions involved in airplane reception that make a specially designed beacon set desirable. The Bureau of Standards have developed a receiving set which is very compact, and has a total weight of less than 30 pounds. It may be used to receive either beacon signals, radio telephone, or telegraph messages. The trailing wire antenna has been done away with and in its place a 10-foot metal pole extending vertically from the cockpit is used. The set itself has a remote control arrangement so it may be placed in some out of the way place. The indicator is mounted on the instrument board.

30. Over established airways directive beacons will probably be located about 200 miles apart, and at the principal airports. Small "marker beacons" of a non-directive character will be placed along the route at short intervals, each giving a characteristic signal which will be heard by the plane for a minute or two, and the pilot will then know he is passing some specified point.

EXAMPLES FOR STUDY

31. Each of the following examples should be carefully studied and worked. Master them step by step, and should any part be a bit confusing, turn back and study the text again. For convenience the problems have been confined to the state of Illinois and worked on a Rand McNally Standard State Map, copies of which may be obtained at any map or stationery store. A copy of this map should be at hand, together with a protractor and a pair of dividers, before starting work.

32. The time of flight may be conveniently found by the following formula:

$\frac{a}{g} \times \frac{D}{1} = X$, in which a is the number of minutes in one hour, g is the ground speed, D the distance of the trip, and X the time in minutes required to make the flight.

33. Determination of drift angle and ground speed should be made on the map. However, as it is sometimes confusing to a beginner just which way to apply the leeway, diagrams of each problem are given and should be considered carefully.

34. Do not merely study the worked out examples. Rework each one, and do not leave it until it is thoroughly understood. Know *the reason why* each operation is performed, and do not work blindly by rule.

Deviation Card

Magnetic head	N.	15	30	45	60	75	E.	105	120	135	150	165
Deviation	0	1W.	3W.	4W.	3W.	2W.	1W.	1E.	3E.	4E.	5E.	4E.
Magnetic head	S.	195	210	225	240	255	W.	285	300	315	330	345
Deviation	2E.	3E.	5E.	6E.	4E.	1E.	2W.	0	1E.	2E.	3E.	2E.

35. For both examples for study and practice deviations are taken from the table given below, and variation from variation chart accompanying this book.

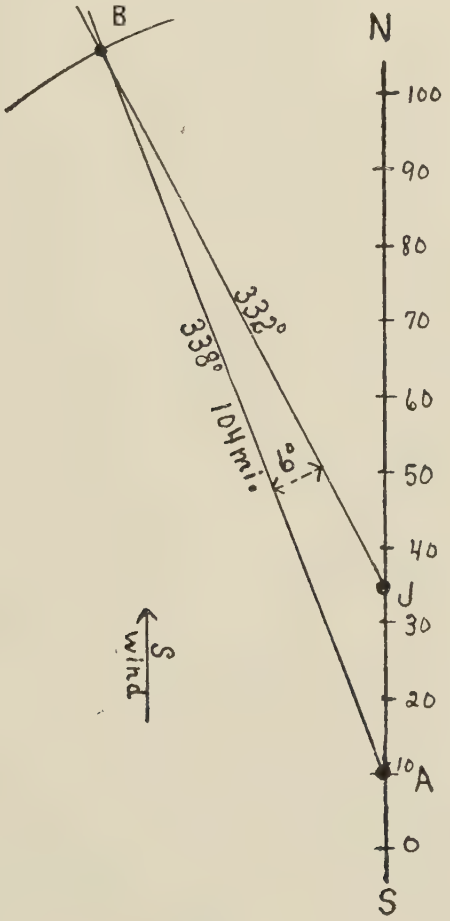


FIG. 82

Example 1. A plane whose cruising speed is 80 miles per hour is bound from Springfield to Moline. The wind is south, 25 miles per hour. What is (a) the true course? (b) the magnetic course? (c) the compass course? (d) distance in statute miles? (e) lee-

way? (f) course to steer? (g) ground speed? (h) length of time required for trip?

Solution 1:

(a) True course ..... 338°
Variation ..... 4° E.

(b) Magnetic course ..... 334°
Deviation ..... 2° E.

(c) Compass course ..... 332°
(d) Distance ..... 126 miles
(e) Leeway (figure 82) ..... 6°
(f) Compass course ..... 332°
Leeway (figure 82) ..... 6°

Course to steer ..... 326°
(g) Ground speed (figure 82) ..... 104 m.p.h.
(h) Distance from Springfield to Moline—126 miles, and the ground speed is 104 m.p.h. The number of minutes required to make the flight will therefore be $\frac{60}{104} \times \frac{126}{1} = 72.8$ minutes or 1 hour 13 minutes.

Example 2. A plane whose cruising speed is 75 miles per hour is bound from Kankakee to Quincy. Wind, north, 30 miles per hour. What is the (a) true course? (b) magnetic course? (c) compass course? (d) distance in statute miles? (e) leeway? (f) course to steer? (g) ground speed? (h) length of time required for the trip? (i) what time will the plane pass Peking? (j) a drift indicator is being used at regular intervals, and after flying some time, the drift angle is measured and found to be 15°. What does this signify, and what must be done?

Solution 2:

(a) True course ..... 247°
Variation ..... 4° E.

(b) Magnetic course ..... 243°
Deviation ..... 4° E.

(c) Compass course ..... 239°
(d) Distance ..... 203 miles
(e) Leeway (figure 83) ..... 21°
(f) Compass course ..... 239°
Leeway (figure 83) ..... 21°

Course to steer ..... 260°
(g) Ground speed (figure 83)..... 82 m.p.h.
(h) The distance is 203 miles, ground speed 82 m.p.h., therefore the number of minutes required to make the trip is

$$\frac{60}{82} \times \frac{203}{1} = 148.5 \text{ minutes or 2 hours 28 minutes}$$

(i) The distance from Kankakee to Peking is 100 miles, $\frac{60}{82} \times \frac{100}{1} = 73.1$ minutes, or the plane will pass about one mile southeast of Peking 1 hour 13 minutes after leaving Kankakee.

(j) The strength or direction of the wind, possibly both, have changed causing the drift angle to change from 21° to 15°, a decrease of 6°. The course to steer must be corrected accordingly as follows:

Compass course ..... 239°
Leeway ..... 15°

Course to steer ..... 254°

In actual practice the course may be corrected by increasing or decreasing the course to steer as the drift angle is found to change. Thus 260° — 6° = 254°, or the new course to steer.

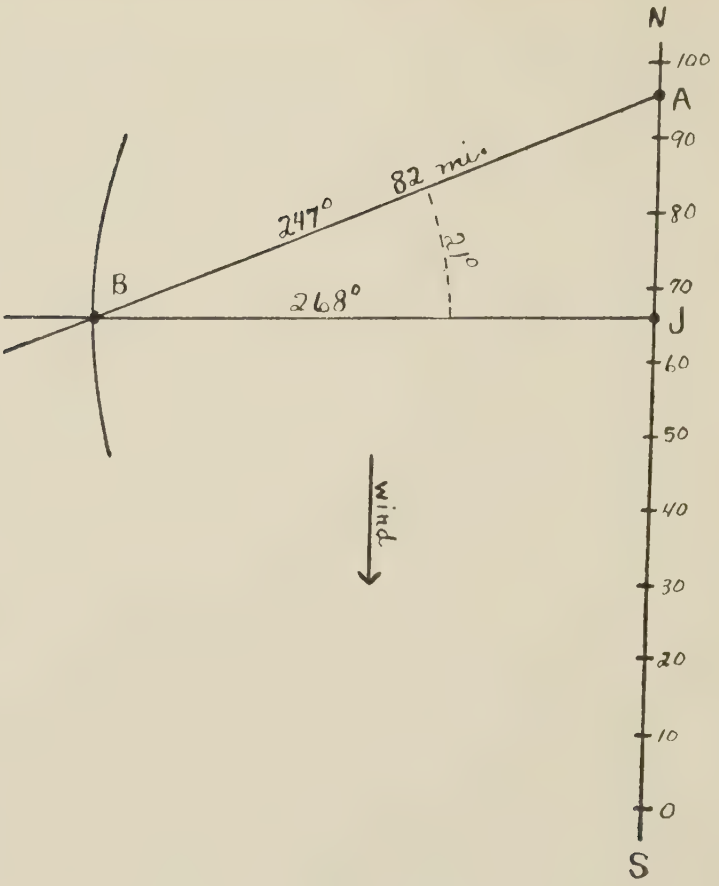


FIG. 83

Example 3. A plane whose cruising speed is 100 miles per hour is bound from Moline to Kankakee. Wind northeast, 25 miles per hour. Find the (a) true course; (b) magnetic course; (c) compass course; (d) distance in statute miles; (e) leeway; (f) course to steer; (g) ground speed; (h) length of time required for trip; (i) after flying blindly for some time the ship is found to be over the city of Ottawa. What is the course error, and what course must be steered to make Kankakee?

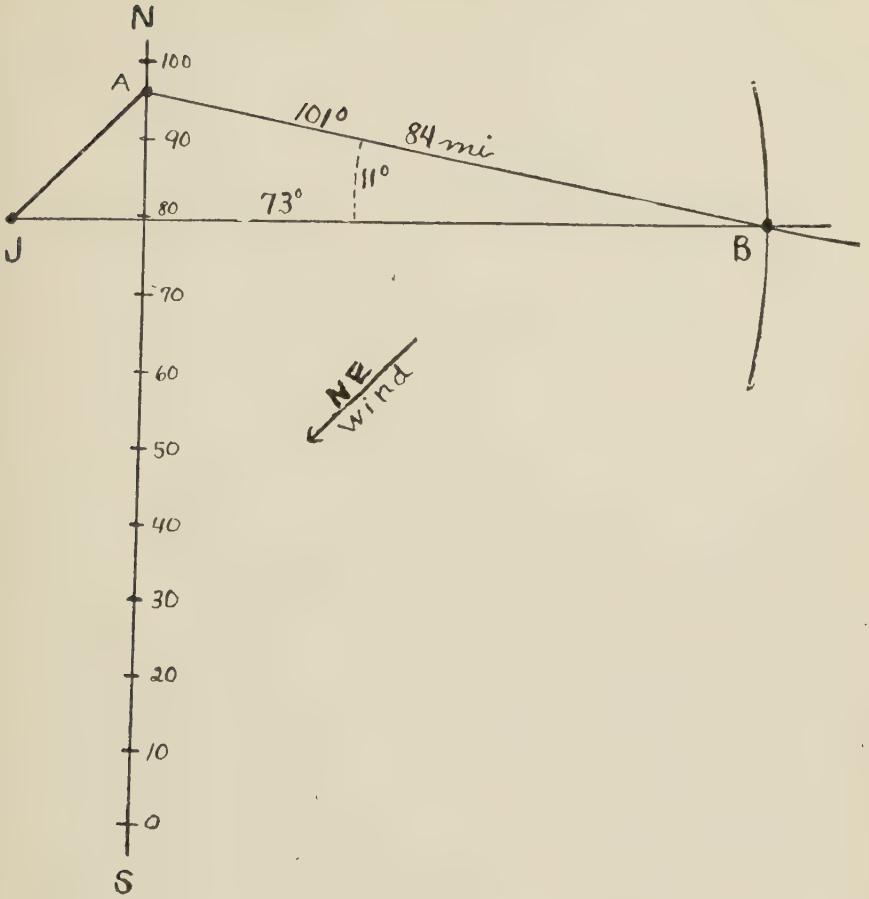


FIG. 84

Solution 3:

(a)	True course	101°
	Variation	3° E.
(b)	Magnetic course	98°
	Deviation	1° E.
(c)	Compass course	97°
(d)	Distance	140 miles
(e)	Leeway (figure 84)	11°

(f) Compass course ..... 97°
Leeway (figure 84) ..... 11°

Course to steer ..... 86°
(g) Ground speed (figure 84) ..... 84 m.p.h.
(h) Distance from Moline to Kankakee is 140 miles, and the ground speed is 84 m.p.h., therefore the number of minutes required to make the trip will be $\frac{60}{84} \times \frac{140}{1} = 100$ minutes or 1 hour 40 minutes.
(i) Course error is 3°. Course to steer to Kankakee is 91°.

Example 4. A plane whose cruising speed is 90 miles per hour is bound from Chicago to Springfield. Wind is from the northwest, 20 miles per hour. What is (a) the true course? (b) magnetic course? (c) compass course? (d) distance in statute miles? (e) leeway? (f) course to steer? (g) ground speed? (h) length of time required for trip? Make up a time table showing the lapse of time and distance from point of departure to the principal landmarks.

Solution 4:

(a) True course ..... 216°
Variation ..... 3° E.

(b) Magnetic course ..... 213°
Deviation ..... 5° E.

(c) Compass course ..... 208°
(d) Distance ..... 178 miles
(e) Leeway (figure 85) ..... 13°
Compass course ..... 208°
Leeway (figure 85)..... 13°

(f) Course to steer ..... 221°
(g) Ground speed (figure 85) ..... 92 m.p.h.

(h) Distance, Chicago to Springfield = 178 miles ground speed = 92 m.p.h. The number of minutes required to make the flight therefore will be

$$\frac{60}{92} \times \frac{178}{1} = 116 \text{ minutes or } 1 \text{ hour } 56 \text{ minutes.}$$

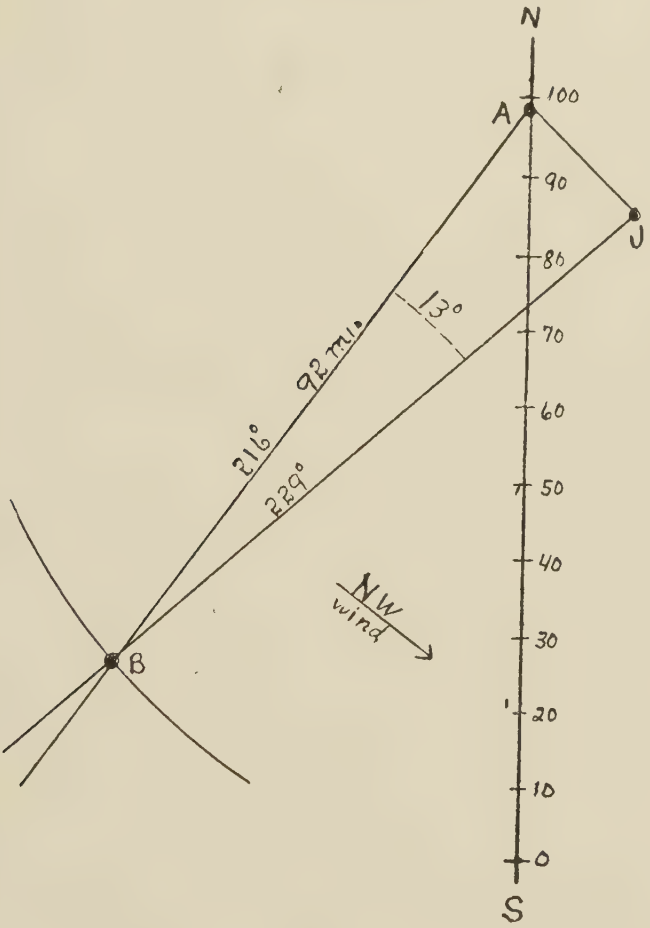


FIG. 85

Example 5. A plane bound from Rockford to Springfield has steered the course carefully, but has made none of the chosen landmarks. Looking over his map the pilot discovers he has

Time Table

Time	Distance	Landmark
0 0 0	0	Take Off
10 min.	16 —	Cross canal running east and west. Railroad will parallel course 3 miles left for next 15 miles.
21 min.	32	Joliet 3 miles right. Cross two R.R. about mile apart running east and west—another R.R. 3 miles ahead running N.W.
26 min.	40	Elwood—small town cross R.R. runs about 200°. Pass over town.
31 min.	47	Cross river running N.W. and S.E. bridge 2 miles right, another 2 miles left. R.R. on left draws closer for next 15 miles.
44 min.	68	Small town—Dwight-Passover R.R. runs about 220°, another E. & W. about ½ mile south R.R. runs west only. R.R. close on right for next 18 miles.
55 min.	85	Pontiac—6 R.R. leaving town running N.E., E., S.E., S.W., W., N.W. Small river running N.W.&S.E. about 1 mile south of town. R.R. stays close on left next 35 miles.
1 h. 18 min.	119	Bloomington—large town. Pass over N.W. edge. 9 R.R. leading into town. Working toward R.R. on left, cross same about 15 miles it stays close on right.
1 h. 37 min.	149	Lincoln—small town, 1 mile right 5 R.R. entering, double from S.W. Small river running N.E. and S.W. about 2 miles N.W. of town. Another 2 miles S. of town double R.R. about 1 mile on right for next 30 miles.
1 h. 56 min.	178	Springfield.

been steering 174° instead of the correct course. There is no wind. If the air speed is 70 miles per hour, and the ship has been flying 53 minutes, what is the ship's position and how may it be verified?

Solution 5:

Steering course	174°
Leeway	0°
Compass course	174°
Deviation	2° E.
Magnetic course	176°
Variation	4° E.
True course made good	180°

As there is no wind to consider, the ground speed is 70 m.p.h.

Therefore $\frac{53}{60} \times \frac{70}{1} = 61.8$ miles is the distance made good in 53 minutes. Plotting a position 61.8 miles on the bearing 180° true from Rockford, the plane is found to be about 3 miles north of La Salle. This may be verified by positively identifying the town of La Salle. According to the map, it is a fair sized town, located on the north side of a canal which runs about east and west. A railroad and an electric line enter from the east and leave towards the west, the electric line being north of the railroad. Two railroads enter from a northerly direction and leave in a southerly direction. A large town should be visible about 12 or 13 miles to the eastward and a small town to the west. Just west of the town the canal joins a river running about east and west.

Example 6. A plane whose ground speed is 90 miles per hour is bound from Bloomington to Chicago, steering 10 degrees, which

included 10° leeway for a northwest wind. Low hanging clouds prevented checking the position by landmarks and after flying 1 hour 18 minutes a landing was made in an open field. What was the position of the ship when the emergency landing was made, and what is the compass course and the distance to Chicago?

Solution 6:

Steering course	10°
Leeway	10°
Compass course	20°
Deviation	2° W.
Magnetic course	18°
Variation	4° E.
True course made good	22°

As the ground speed is 90 m.p.h., and the time of flight 78 minutes, the distance made good is $\frac{78}{60} \times \frac{90}{1} = 117$ miles on true course 22°. Plotting this bearing and distance on the map the position is found to be about 8 miles east of Elgin.

True course to Chicago	113°
Variation	3° E.
Magnetic course	110°
Deviation	2° E.
Compass course	108°

The distance measured from the map is 28 miles.

EXAMPLES FOR PRACTICE

Example 1. A plane with a cruising speed of 95 miles per hour is bound from Kankakee, Ill., to Champaign, Ill. There is a 25 mile wind from the north-northwest. What is the (a) course to steer? (b) ground speed? (c) length of time required to make the flight?

Ans.: (a) 199°
(b) 113 m.p.h.
(c) 39 min.

Example 2. A plane with a cruising speed of 80 miles per hour is bound from East St. Louis to Decatur. There is a 25 mile wind from the east. What is the (a) course to steer? (b) ground speed? (c) length of time required for the flight?

Ans.: (a) 51°
(b) 63 m.p.h.
(c) 1 h. 40 min.

Example 3. A plane with a cruising speed of 90 miles per hour is bound from Moline to Springfield. There is a 20 mile north wind. What is the (a) course to steer? (b) ground speed? (c) length of time required for the flight?

Ans.: (a) 144°
(b) 110 m.p.h.
(c) 1 h. 9 min.

Example 4. A plane with a cruising speed of 85 miles per hour is about to make a flight from Rockford to Bloomington and return. There is a 30 mile south-southeast wind. What is the (a) course to steer from Rockford to Bloomington? (b) from Bloomington to Rockford? (c) flying time required for entire trip?

Ans.: (a) 165°
(b) 2°
(c) 3 h. 16 min.

Example 5. A plane left Decatur steering 13°, which included 7° leeway for a west wind. The ground speed was 95 miles per hour. After flying 1 hour 20 minutes a town was sighted directly below. What town was it?

Ans.: Joliet.

Example 6. A plane left Springfield steering 21°, which included 8° leeway for a north-northeast wind. The ground speed was 80 miles per hour. A forced landing was made after the plane had been in the air 1 hour 36 minutes. What was the position of the landing?

Ans.: 2 miles north of Morris.

Example 7. What will be the flying time for a trip from Peoria to Danville and return, assuming a 25 mile west-northwest wind remains constant, and an air speed of 100 miles per hour is maintained?

Ans: Peoria—Danville = 54 min.
Danville—Peoria = 1 h. 30 min.

CHAPTER IX

METEOROLOGY

1. The earth is entirely enveloped by a gaseous body known as the atmosphere (air). The height of the atmosphere is far greater than any height that can be reached by ordinary means, and meteorologists agree its extent is probably more than 200 miles. The density of the atmosphere is maximum at the earth's surface and gradually decreases with altitude. Its principal ingredients are Nitrogen 78%, and Oxygen 21%, approximately. Other gases form about 1%.

2. Light and unsubstantial as the atmosphere appears to the average observer, it has a positive weight, and as such, exerts a pressure on the earth's surface of approximately 15 pounds per square inch at sea level. The amounts of this pressure varies with altitude and density of the air, being greatest at sea level and decreasing gradually with increased height. Thus the pressure of the atmosphere would be the same at all places having a common height above the level of the sea if it were not for the disturbing influence of heat, and the movement of air caused by unequal heating of the earth's surface.

3. The instrument used for measuring atmospheric pressure is called a *barometer*. There are two kinds of barometers in general use—*mercurial* and *aneroid*.

4. Figure 86 shows a mercurial barometer. The principle of the instrument may be explained about as follows: A glass tube which is closed at one end, and measuring about 3 feet long and 1/3 inch in diameter, is filled with mercury. The finger is then held over the open end and the tube turned vertically with open

FIG. 86

end down, into a cup or container. Some of the mercury will now flow from the tube into the cup, until the pressure of the atmosphere on the surface of the mercury in the cup is equal to the weight of the mercury remaining in the tube. The space above the mercury in the tube is a vacuum, consequently there is no pressure on top of the column. If the pressure of the atmosphere on the surface of the mercury in the cup is increased, the column of mercury in the tube will be forced up, and likewise, if the pressure of the atmosphere is decreased the column in the tube will go down.

5. The glass tube and cup are protected by a metal casing. Near the top of the tube, a graduated scale and vernier is fitted so the height of the column of mercury may be measured to 1/100 of an inch. An accurate thermometer is usually attached to the instrument so temperature may be noted when the barometer is read. This is necessary as mercury expands and contracts with increase and decrease of temperature. For this reason, all barometric readings must be reduced to what is termed *Standard Temperature,* which is 32° F., when a column of mercury stands 30 inches. The mercurial barometer is a delicate instrument and should be handled accordingly. When suspended for use, it should hang in a vertical position, be protected from the direct rays of the sun and local sources of heat and cold.

6. Figure 87 shows an aneroid barometer. These instruments are made in various sizes and ranging from a 3- or 4-inch to a 12-inch face. They consist of a cylindrical metal box with a thin corrugated back. When the atmospheric pressure increases, the back is pressed in, and when it decreases the back is pressed out, partly by its own elasticity and partly by the aid of small springs. These movements are transmitted and multiplied by a set of delicate levers acting on an index pointer and causing it to move either right or left over a graduated scale. These instru-

ments are self-correcting for variation of temperature. They are portable and so very sensitive (when well made) that they show a difference in pressure when moved from the floor to the upper part of a room. They should be handled very carefully as they are easily injured. A good aneroid barometer may be purchased

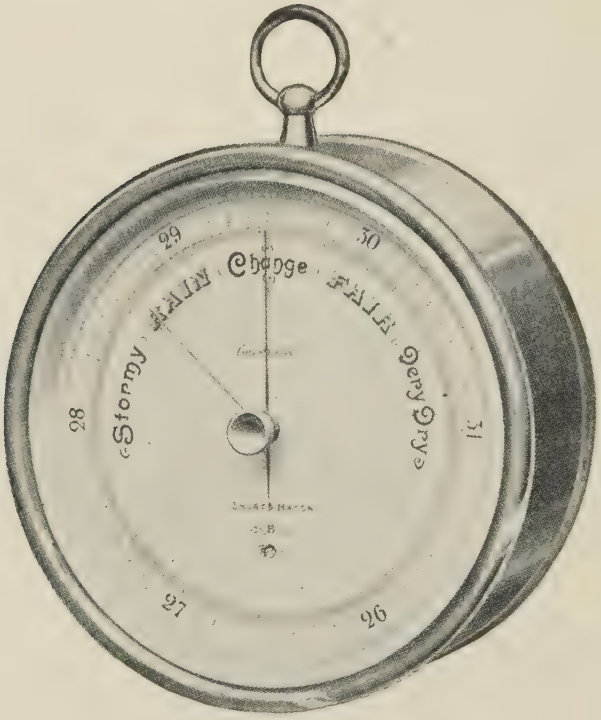


Fig. 87

for from $25 to $50, and is an excellent weather glass if carefully observed, but its readings are not as accurate as a mercurial barometer.

7. Readings of mercurial barometers must be corrected to 32° F. and to standard gravity, by the tables given on page 167, in order to compare them with the pressure shown on the weather map. Aneroid barometers require no correction for gravity.

To 32° Fahrenheit				To standard gravity			
Att. Ther.	Corr.	Att. Ther.	Corr.	Lat.	Corr.	Lat.	Corr.
°	In.	°	In.	°	In.	°	In.
40	—.08	70	—.11	0	—.08	30	—.04
50	—.06	80	—.14	10	—.08	40	—.01
60	—.08	90	—.17	20	—.06	50	+.01

8. An area of ascending air currents is usually termed a *low pressure area,* or *cyclone area.* The weather of all such regions is characterized by more or less cloudiness, frequently accompanied by rain, by low barometer, and by winds which while not necessarily of gale force, are usually stronger than in an area of high pressure, since the determining cause of these winds—are upward rush of warm air—naturally takes on a somewhat more violent form than does the downward flow of cool, heavy air causing the *area of high pressure* or anti-cyclonic area.

9. Air is like water in its tendency to flow, the direction of the air flow being from the high pressure area to the low, and this movement of air is wind. This wind does not travel in straight lines, however, but leaves the high pressure area in more or less of a spiral *with the clock,* and flows into the low in the same way but *against the clock.* In other words, wind spiral to the right on leaving the high and spiral to the left on entering the low. These conditions are reversed in the southern hemisphere where the wind leaves the high against the clock and enters the low with the clock. The velocity of the wind, as well as its direction, depends on *relative pressures in adjoining areas,* and their distance apart. For instance, a high that is not very much above normal, and a low but slightly below normal, well separated, will have very little flow of air from one to the other, but an unusual high quite

near an unusual low will result in a rapid flow of air causing winds of gale force. The difference in the barometer between two places is termed the *barometric gradient.* Where the difference is very great for a small change of position, the gradient is said to be *very steep,* and at such places the velocity of the wind will be high. Where the change is more gradual, it is said to *slope,* and winds are more moderate.

10. The indrawn air of the low pressure area obtains moisture by evaporation from damp earth, rivers, the sea, etc., etc. The capacity of the atmosphere for holding moisture in invisible suspension increases rapidly with temperature, and for a given quantity of moisture so suspended, there is a definite temperature called the *saturation point* or *dew point,* below which the air cannot be cooled without giving out some of its moisture in the form of cloud or rain.

11. This is why the warm, moist air currents from the surface of the earth, as they rise into the cooler regions of the upper atmosphere, produce the clouds and rainfall so characteristic of the low pressure area. It is also the reason for the comparatively clear skies and dry weather of the high pressure area; since the cool dry air currents flowing from the higher atmospheric regions downward and outward has its temperature raised as it nears the surface of the earth, and is enabled to take up into invisible suspension much of the moisture it encounters, thus producing a dry atmosphere and clear skies. On the other hand, as air rises it expands more and more, cooling at the same time through the absorption of heat due to this expansion, while it is still further chilled by the lower temperature of the upper regions of the atmosphere. As a consequence of a reduction in temperature, much of the aqueous vapor is condensed into clouds or precipitated in rain, giving off a large amount of heat, which tends to rarefy the air still further and so to intensify the upward draft.

12. The actual amount of water vapor held in invisible suspension is called *absolute humidity*. The amount of water vapor present at any given time, as compared with the amount present at the saturation point is known as *relative humidity*, and is expressed in a percentage.

13. Relative humidity is found by comparing the reading of a thermometer whose bulb is incased in a damp wick, with the reading of another thermometer whose bulb is exposed to the air. They are respectively known as the *wet* and *dry bulb*.

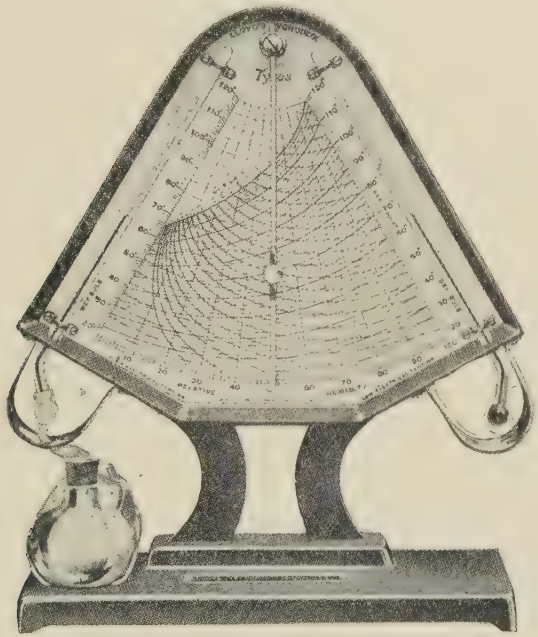


FIG. 88

14. Figure 88 shows an instrument known as the *hydrodeik*, which consists of both wet and dry bulb thermometers mounted on a chart on the side margins of which the temperature ranges are engraved. To find the relative humidity, it is merely necessary to swing the index hand of the scale at the left of the chart

and set the sliding pointer at the degree line on the chart corresponding to the temperature shown by the wet bulb. The index hand is then swung to the right until the sliding pointer intersects the curved line which extends downward to the left from the degree line corresponding to the temperature shown by the dry bulb. At this intersection, the index hand will point to the relative humidity on the scale at the bottom of the chart.

15. It would be natural to expect a belt of low pressure, with its attendant ascending air currents, in the vicinity of the geographical equator, and such is actually the case. Such an equatorial belt commonly known as *Doldrums,* completely circles the globe; the phenomena of expansion from heat, ascending air currents with resulting low barometer, of condensation and precipitation, is much more frequent and marked here than elsewhere.

16. Observation of winds, temperatures and pressures extending over a long period of years indicate the existence in the polar regions of an area of low barometer about which the wind blows with the characteristic low pressure direction, giving rise to the constant westerly winds above latitude 40° north and 40° south. This condition, of course, cannot be due to the causes which produce the low pressure belt in the equatorial region; and the commonly accepted theory accounts for it as the result of centrifugal force acting upon the mass of the atmosphere as it is whirled about by the earth's rotation. Whether this explanation is correct or not, the fact remains that there is abundant evidence that the pressure is permanently low in the vicinity of the poles as well as at the equator, and there exists a belt of generally high pressure in the neighborhood of 30° north and 30° south, from which the low pressure areas tend to draw, on one hand toward the equator and on the other toward the pole. This distribution of pressure gives rise to winds that blow constantly, or nearly so, from one given direction.

17. By keeping in mind the general distribution of pressure as described above, no difficulty will be experienced in understanding the cause of what are termed *Constant Winds.*

18. The trade winds blow constantly from the northeast in the northern hemisphere and from the southeast in the southern hemisphere. Their area of operation extends from approximately a 30° south to 30° north with a narrow belt of calm between and near the equator, known as the doldrums. The causes of the trade winds were a puzzle to meteorologists for many centuries. However, the present accepted explanation seems to be about as follows: it is well known that warm air is lighter than cold air, therefore, the warm air of the equilateral regions, being heated to a considerable degree, will rise, and in its place will flow cool air from the direction of the poles. Winds are thus established, one blowing from the poles towards the equator along the surface of the earth, and another from the equilateral regions toward poles in the upper atmosphere. If the earth were at rest, a northerly surface wind would prevail in the northern hemisphere and a southerly surface wind in the southern hemisphere. The earth's rotation from west to east however, gives a strong eastern component. The result of the two forces, that is, the rotation of the earth from west to east and the natural tendency of the wind to travel from the poles to the equator, cause trade winds.

19. Just outside the borders of the trade winds, in both the northern and southern hemisphere is a region of light and variable winds known as the *Horse Latitudes.* These regions are marked for comparative clear and fresh weather.

20. Outside the horse latitudes, and all across the temperate zone, in both northerly and southerly latitudes, westerly winds predominate, though they are frequently interrupted by storms and occasional shiftings. For example, between 40° S. and 60° S. the wind blows continuously from some westerly point. There

are exceptions of course, but taking the average wind directions for a given time, the resultant of the several components will be westerly.

21. Winds that blow from a given direction for a certain period and then change or reverse themselves with marked regularity are known as *Periodic Winds*. The monsoons of the Indian Ocean and China Sea are the most famous of this class. Throughout the whole of this region, between 30° N. in India and 20° S. between Madagascar and Australia, the wind is reversed every six months. Like the trade winds, the monsoons are caused by inequality of heat in different regions as well as the rotation of the earth.

22. Winds known as land and sea breezes are invariably met along the coastal regions of the tropic and temperate zones. The probable cause of these winds is due to the land becoming heated more rapidly than the sea during the day and cooling more rapidly during the night. In the morning, the air over the land will become heated from the sun more quickly than that over the sea, and rise, and the cool air from the sea will flow in. In the evening, the conditions will be reversed.

23. Winds that blow without any marked regularity as to time and place are usually termed *variable winds*. A sudden storm coming on with little or no warning is of this class and are known by various names in different parts of the world, such as: the *Northers of the Southern States;* the *Pampero of South America;* and the *Khamsin of Egypt*. The term variable winds, is also applied to light shifting winds that come from first one point and then another but from no particular place for any great length of time.

24. The regions of the trade winds are seldom invaded by storms, and are marked by the most pleasant weather conditions imaginable. The same might be said of the horse latitudes, but to

a less degree. Outside the horse latitudes, in the region of westerly winds, there are frequent fluctuations of the weather near the surface of the earth, which often delay, arrest, and even turn back the prevailing wind temporarily. In the upper regions, the atmosphere continues its eastward flow without interruption, though not with unvarying velocity. These disturbances are caused by different atmospheric pressure in adjacent regions, and result in high and low pressure areas having exactly the same characteristics as the permanent high and low areas already described.

25. In the continued eastward movement of the air, (for example, across the North American Continent and the North Atlantic Ocean), is found the key to the fluctuations of weather, as well as the possibility of predicting from day to day approximately what weather may be expected at a given place. Atmospheric disturbances—highs and lows, with the weather features which have been described as characteristics of each—sweep across the continent in a regular procession, following a line which may vary considerably, but will always be toward the east.

26. The areas of low pressure, or storm areas as they are sometimes called, usually originate in the western part of the continent, or may enter it from the Pacific Ocean; but their movement is invariably to the eastward, and they leave by the Atlantic seaboard, usually by way of the New England Coast or the Gulf of St. Lawrence. Thus, there is a constant movement from west to east of waves of atmospheric pressure, much like the waves of the sea. These pressure waves are not of regular height like ocean waves, but resemble an irregular range of mountains in which the peaks are high pressure, or anti-storm areas, and the troughs and valleys are low pressure, or storm areas. As these waves of atmospheric pressure pass over a given locality, the

barometer will rise or fall just as some floating object would do if riding ocean waves.

27. An examination of the weather maps published by the United States Weather Bureau for several successive days gives an interesting view of the daily movements of storm and anti-storm areas, toward the east, and also gives a good general idea of the laws upon which weather forecasting is based. Figure 89 shows a map of this kind. The corresponding map for the following day would show the successive highs and lows as having moved to the eastward, carrying with them their characteristic features of wind-circulation, cloud or clear sky, temperature, rain, etc.

28. Weather maps present an outline of the United States and Canada, showing the stations where weather observations were taken at 8 A.M. and 8 P.M., seventy-fifth meridian time. These observations consist of reading the barometer, thermometer (wet and dry), direction and velocity of the wind, state of the weather, amount and kind of clouds, and amount of rain or snow. They are telegraphed to Washington and to many of the Weather Bureau stations throughout the country for publication on maps. In making up the maps solid lines, called *isobars,* are drawn through points having the same atmospheric pressure; a separate line being drawn for each difference of one-tenth of an inch. Dotted lines, called *isotherms,* connecting places having the same temperature are drawn for each ten degrees of the thermometer. The direction of the wind is indicated by arrows flying with the wind. The state of weather—clear, partly cloudy, cloudy, raining or snowing—is indicated by a circular symbol.

29. The alternating high and low areas have an average easterly travel of from five to six hundred miles per day, though this may vary greatly. High winds, with rain or snow, usually precede the low areas (storm areas), often extending four or five hundred miles to the eastward of the center of the storm. In advance

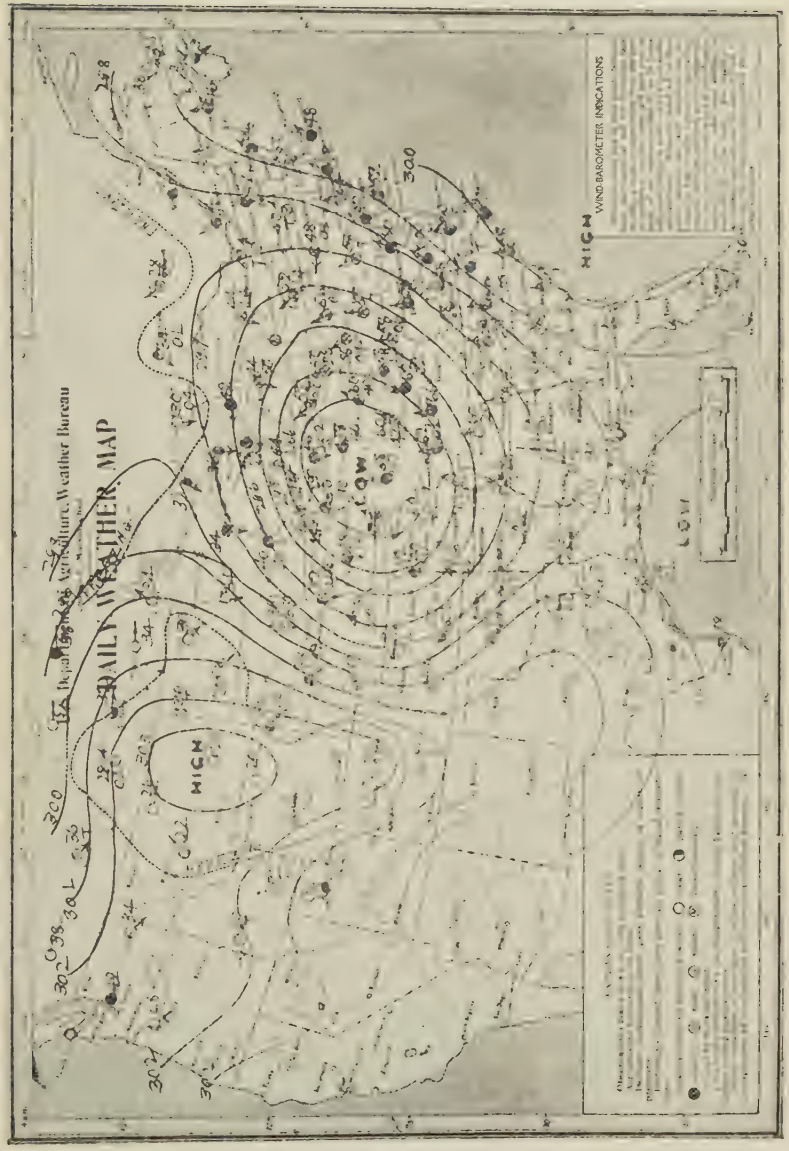

DAILY WEATHER MAP
U.S. Department of Agriculture, Weather Bureau
HIGH
LOW
HIGH
WIND-BAROMETER INDICATIONS
LOW

FIG. 89

of the low, winds are generally southerly, and consequently bring high temperatures. When the center of the low passes to the eastward of a given locality, the wind shifts to the west or northwest, bringing lower temperatures. The temperature on a given parallel west of the low may be reasonably looked for on the same parallel to eastward after the low has passed. Following the low usually comes an area of high, bringing clear weather, which in turn is followed by another low.

30. By bearing in mind the general rules as to direction, and rate of movement of the low- and high-pressures areas, with the blowing of wind from the high to the low, and the studying of the map carefully, coming weather may be forecasted.

31. The center of lows do not, as a rule, move across isotherms, but follow their general direction. Low pressure areas frequently move to the south of east from the Rocky Mountains to the Mississippi River, and then change direction to the north of east over the eastern half of the country. Storms in the Gulf of Mexico occasionally move to the west of north, but after reaching the coast they generally change direction and move northeastward. High-pressure areas usually move to the southeast and are usually attended by fair and cooler weather. A cold wave is always accompanied by a high.

32. The cloud and rain area in front of a low, is generally about the size of a low area itself, and is oval in shape, with the west side touching the center of the disturbance in advance of which it progresses.

33. When the isotherms run nearly east and west no decided temperature change will occur. If the isotherms directly west of a given locality run northwest and southeast, it will be warmer; if from northeast to southwest, it will be colder.

34. Southerly to easterly winds prevail west of a north-and-south line passing through the center of a high, also east of a similar line

passing through a low. Northerly to westerly winds occur east of a north-and-south line passing through the center of a high; also west of a similar line passing through a low.

35. Absence of any decided waves of high or low pressure indicate a continuance of existing weather, which will last until such a change makes its appearance. An understanding of the above principles will make it clear why bad weather in the eastern part of the United States invariably begins with an easterly wind and clears off with a cold northwester.

36. In addition to the daily weather maps, the Hydrographic Office publishes a monthly forecast of average weather and wind conditions of the upper air known as the "Pilot Chart of the Upper Air—North Atlantic Ocean." These forecasts are based on millions of observations taken over a period of years and many valuable deductions are made with regard to wind and weather.

37. In weather reports and meteorological work in general, the force of the wind is given by Beaufort scale, in which a dead calm is force 0, and a hurricane is force 12. The scale, figure 90, is given here together with the terms used in the United States Weather Bureau forecasts.

38. The most important and interesting features in connection with weather, next to wind circulation, are the phenomena of precipitation and temperature changes. As has already been explained, there is a tendency toward precipitation in the upward draft of a low; but it is found that in the case of the lows moving to the eastward across the United States, the precipitation is much greater along the forward part of the storm area and in its eastern and southern quadrants than to the northward and westward. The explanation is that the winds of the eastern and southern quadrants are largely drawn from the warm regions of the Southern States and from the Gulf of Mexico, and are charged

Beaufort No.	Seaman's description of wind.	Specifications for use on land.	Miles per hour (statute).	Equivalent in knots.	Equivalent in meters-per second.	Equivalent pressure in millibars * (10^3 dynes per cm^2).	Terms used in U. S. Weather Bureau forecasts
0	Calm	Calm; smoke rises vertically....	Less than 1	Less than 1	Less than 0.3	Less than 0.005	Light.
1	Light air.....	Direction of wind shown by smoke drift, but not by wind vanes.	1-3	1-3	0.3-1.5	0.005-0.03	
2	Light breeze (slight breeze)	Wind felt on face; leaves rustle; ordinary vane moved by wind.	4-7	4-6	1.6-3.3	0.03-0.1	
3	Gentle breeze...	Leaves and small twigs in constant motion; wind extends light flag.	8-12	7-10	3.4-5.4	0.1-0.2	Gentle.
4	Moderate breeze	Raises dust and loose paper; small branches are moved.	13-18	11-16	5.5-8.0	0.2-0.5	Moderate.
5	Fresh breeze....	Small trees in leaf begin to sway; crested wavelets form on inland waters.	19-24	17-21	8.1-10.7	0.5-1.0	Fresh.
6	Strong breeze...	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	25-31	22-27	10.8-13.8	1-1.5	Strong.
7	Moderate gale (high wind)..	Whole trees in motion; inconvenience felt in walking against wind.	32-38	28-33	13.9-17.1	1.5-2	
8	Fresh gale.....	Breaks twigs off trees; generally impedes progress.	39-46	34-40	17.2-20.7	2-3	Gale
9	Strong gale.....	Slight structural damage occurs (chimney pots and slate removed).	47-54	41-47	20.8-24.4	3-4.5	
10	Whole gale (heavy gale)..	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	55-63	48-55	24.5-28.3	4.5-6	Whole gale.
11	Storm	Very rarely experienced; accompanied by widespread damage.	64-75	56-65	28.4-33.5	6-8	
12	Hurricane	.....	Above 75	Above 65	33.6 or above	Above 8	Hurricane.

FIG. 90

with moisture which they deposit as they sweep northward and at the same time rise into the cooler regions of the upper atmosphere. Thus, in northern latitudes, rain comes with an easterly or southerly wind and winds from the northern and western quadrants are relatively dry and cold.

39. The explanation given above suffices, in a general way, to account for the succession of warm and cool waves which are more or less characteristic of the highs and lows. It has already been explained that a low is an area of ascending warm air, while a high is an area of descending cold air. But a close inspection of the weather maps will show that in addition to this we have on the forward side of an advancing low, a southerly or southeasterly wind, drawing up from the warm regions of the tropics; while in front of an advancing high we have a northerly or northwesterly wind sweeping down from the cooler country.

40. The laws of atmospheric circulation which have been given are subject to many exceptions, due to the irregular distribution of land and water, and other circumstances which break up the symmetry of an ideal globe. Of the modifications thus introduced, the outstanding example is the enormous change over the continent of Asia from winter to summer, causing what is known as the *reversal of the monsoons*.

41. The land is heated excessively during the summer months, and the air in contact with it is heated and rises, creating an upward current of sufficient power to overcome the effect of the similar current in the equatorial belt, and to turn back the northeast trade wind on its track, converting it into the southwest "monsoon," which blows constantly and sometimes with great force, for several months of the year. After the continent has cooled sufficiently to restore the normal balance of pressure, the trade wind again sets in under the local name of the northeast monsoon.

42. It is evident from what has gone before that the barometer is by far the most important instrument available for forecasting weather, and it is deserving of much more exact attention than it usually receives. To draw any definite conclusions from the barometric readings, we must know the normal pressure of the locality. For example, the normal summer pressure of a place near the Aleutian Islands is 29.60 inches, while that of the north central United States is 30.20 inches. Readings must be taken at regular intervals and carefully recorded.

43. The normal pressure of any locality may be expected to show a daily fluctuation or "barometric tide," which is entirely independent of variations connected with the weather. These variations are greatest in the tropics, and they disappear altogether in very high latitudes. In the tropics, the barometer will stand about $\frac{1}{10}$ of an inch higher at 10 A.M. and 10 P.M. than it does at 4 A.M. and 4 P.M.

NOTES ON THE WEATHER

44. The use of a barometer as a weather glass is quite common both on land and at sea, but only those that have long watched and carefully compared its readings with prevailing weather conditions are able to foretell more than a rising barometer indicates less wind or less rain; or a falling barometer, more wind, or more rain, possibly both; a high barometer, fine weather; a low barometer, dirty weather. But useful as these general conclusions are in most cases, they are liable to be much in error. Familiarity with the following brief observations will enable one not accustomed to the use of a barometer to use it with immediate advantage.

45. A good barometer usually stands, on an average, about one-tenth of an inch higher with or before polar and easterly winds

than it does with or before equatorial or westerly winds of equal strength and moisture. This peculiarity causes many mistakes to be made. The glass is high, but falling: wind or rain, perhaps both, are expected, yet neither follows to any extent; a shifting of wind only occurs. On the other hand, the glass is low, but rising: fine weather is expected; instead a strong wind, accompanied by heavy rain or snow sets in from the polar direction. By such changes as these, observers are often misled, and serious consequences may result from unpreparedness.

46. There may be nasty weather beyond the horizon, or even within the view of an observer, which will affect his barometer considerably, though no particular change in existing conditions occur in his immediate neighborhood. Sometimes, violent weather from an equatorial direction, of short duration, may cause no great fall, because it is followed by a duration of wind from the direction of the pole. Again, there may be an appreciable fall with polar winds and fine weather continue, apparently against the rule, because, an equatorial wind of long duration is about to follow. Knowledge of these peculiarities are absolutely necessary to the successful forecaster.

47. As a general rule, the barometer *rises* for northerly winds (between northeast and northwest), for dry or less wet weather, for less wind, or for more than one of these changes, except on a few occasions when rain, hail or snow with strong winds come from the direction of the pole.

48. As a general rule, the barometer *falls* for southerly winds (southeast to southwest), for wet weather, for stronger wind, or for more than one of these changes, except on a few occasions when moderate winds and rain or snow comes from the northward.

49. Used in connection with a careful record of barometer read-

ings, force and direction of the wind, and relative humidity, the following guide will be found quite useful:

A sudden rise indicates unsettled weather.

A gradual rise indicates settled weather.

A rise, with dry air and cold increasing, in summer, indicates wind from the northward in northern hemisphere or southward in southern hemisphere, and if rain has fallen, better weather may be expected.

A steady barometer with dry and seasonable temperature indicates a continuance of fine weather.

A rise with southerly winds indicates fine weather in northern latitudes, but wind with rain in south latitudes.

A rapid fall indicates stormy weather. If wind is from the westward, the storm may be expected from the north.

A fall with a northerly wind indicates rain or snow.

A fall with increasing moisture in the air and rising temperature indicates wind and rain from the southward.

A fall after very calm and warm weather indicates rain with squally weather.

50. The table on page 183 is given for handy reference.

THE UPPER ATMOSPHERE

51. For the past few years the United States Weather Bureau has been gathering data relative to wind direction and velocities of the upper atmosphere. A few European countries have been likewise engaged, with the result that the general upper air directions at flying altitudes over North America and Eastern Europe are fairly well known. While very little data is available from other parts of the world, some interesting conclusions may be drawn.

52. Winds at the surface are, on the average, strongest in the

afternoon and weakest in the early morning. The exact opposite of this condition exists aloft, and the stronger winds are found in the morning and weaker in the afternoon. Table 91 is a graph of this condition as shown on the December "Pilot Chart of the Upper Air."

Barometer	*Wind from*	*Weather Indicated*
High and steady.	S.W. to N.W.	Fair and little temperature change for 48 hours.
High and rising rapidly.	S.W. to N.W.	Fair followed by warmer and rain within 48 hours.
High and falling slowly.	S.W. to N.W.	Rain in 24 to 36 hours.
Very high, falling slowly.	S.W. to N.W.	Fair and slowly rising temperature for next 24 hours.
High and falling slowly.	S. to S.E.	Rain within 24 hours.
High and falling rapidly.	S. to S.E.	Increasing wind with rain in 12 to 24 hours.
High and falling slowly.	S.E. to N.E.	Rain in 12 to 18 hours.
High and falling rapidly.	S.E. to N.E.	Increasing wind with rain in 12 hours.
High and falling slowly.	E. to N.E.	Summer, light winds, fair; winter, rain in 24 hours.
High and falling rapidly.	E. to N.E.	Summer, rain in 12 to 24 hours; winter, rain or snow with increasing winds.
Low and falling slowly.	S.E. to N.E	Rain will continue 24 to 36 hours.
Low and falling rapidly.	S.E. to N.E.	Rain and high wind; clearing and cooler in 24 hours.
Low and rising slowly.	S. to S.W.	Clearing soon and fair several days.
Low and falling rapidly.	S. to S.E.	Severe storm soon.
Low and falling rapidly.	E. to N.	Northeast gales with heavy rain or snow.
Low and rising rapidly.	Working to W.	Clearing and colder.

53. It is generally accepted that for every 300 feet of altitude there is a decrease of 1° F. in the temperature, approximately. However, tests conducted by the United States Weather Bureau have shown that there is a wide variation due to change of latitude, and even a wide variation for the same latitude. Table 92, taken from "Pilot Chart, Upper Air," will give a good idea of pressure and temperature changes with altitude.

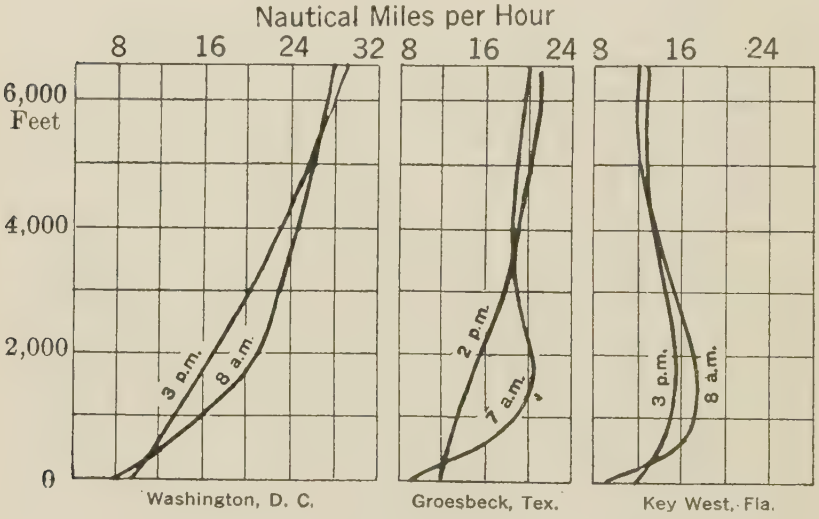


TABLE 91

54. The table on page 185 shows the decrease in atmospheric pressure with increased altitude. This is a particularly interesting as well as important point to the aviator. An altimeter is constructed on the same principle as an aneroid barometer, except its dial is adjustable and is graduated in feet instead of inches. It is apparent, then, that the altimeter will be affected by any change in atmospheric pressure. From the table, we gather that should a barometer, standing at 29.92 and an altimeter set at zero, be taken up in a plane, when the altimeter read 1,000 feet the barometer would read 28.85, a fall of 1.07 inches. Again had

TABLE 92

Altitude, mean sea level *Feet*	Pressure *Inches*	Temperature °*F.*
0	29.92	59.0
1,000	28.85	55.5
2,000	27.82	52.5
3,000	26.82	49.0
4,000	25.84	46.0
5,000	24.90	42.5
6,000	23.98	38.0
7,000	23.09	34.0
8,000	22.23	31.0
9,000	21.39	26.5
10,000	20.58	22.5
11,000	19.79	19.0
12,000	19.03	16.0
13,000	18.29	12.5
14,000	17.57	9.0
15,000	16.88	5.0
16,000	16.21	1.0
17,000	15.56	−2.5
18,000	14.93	−5.5
19,000	14.33	−9.0
20,000	13.74	−12.5
21,000	13.17	−16.5
22,000	12.63	−20.0
23,000	12.10	−24.0
24,000	11.59	−27.0
25,000	11.09	−30.5
26,000	10.62	−34.0
27,000	10.16	−37.5
28,000	9.71	−41.5
29,000	9.28	−45.0
30,000	8.87	−48.5
31,000	8.47	−52.0
32,000	8.09	−55.5
33,000	7.72	−58.5

the plane been left on the ground and an appreciable change in atmospheric pressure occur, say a fall, the altimeter will show a proportionate increase in altitude. For example, assume the barometer should fall $^{53}/_{100}$ of an inch, the altimeter will then *show an altitude of 500 feet, though the plane has not changed its position and is still on the ground.*

55. In practice, a movement of $^{1}/_{10}$ of an inch in atmospheric pressure may be considered to cause a change of 90 feet in the altimeter reading. Thus, a plane leaving Boston, barometer reading 30.20 inches, and arriving in New York with the barometer reading 30.00 inches, will, after landing, find the altimeter shows an altitude of about 180 feet. Incidentally, a change of $^{20}/_{100}$ of an inch between places two or three hundred miles apart is quite common.

56. The tendency of wind is to blow parallel to the isobars, but due to surface friction this tendency is not usually realized, and the movement of surface wind is at an average angle to the isobars of from 20° to 30°. Over flat country and over the ocean, the angle may be as small as 10°, while over rough country, it will go as high as 40° to 50°. The effect of friction is gradually lessened with altitude, and at about 3,000 feet it is completely overcome and the wind then roughly parallels the isobars and is known as a *gradient wind.*

57. Winds aloft generally turn somewhat to the right from the surface direction. This turning is more pronounced with southerly surface winds (southeast to southwest), amounting to as much as 50° or 60° at 5,000 to 6,000 feet. With northerly winds (northwest to northeast) the turning is to the right, but small in amount up to about 2,500 or 3,000 feet, when it then works back to the left. A study of Table 93 indicates that a constant westerly wind might be expected at extreme altitudes. The table

TABLE 93

NORTHERN UNITED STATES

WINTER

Surface Direction	Altitude, Feet					
	820	1,640	3,281	6,562	13,123	19,685
N.	+8	+4	—12	—46	—66	—60
N.N.E.	+5	0	—16	—58	—94	—59
N.E.	+6	+10	—1	—102	—88	—118
E.N.E.	+10	+18	+53	+33	—25	.....
E.	+29	+55	+108	+179	+190	+202
E.S.E.	+16	+43	+86	+140	.....	.....
S.E.	+32	+56	+81	+122	+128	.....
S.S.E.	+25	+43	+68	+94	+118	.....
S.	+22	+38	+62	+77	+96	.....
S.S.W.	+22	+38	+55	+67	+79	.....
S.W.	+19	+31	+45	+54	+62	+68
W.S.W.	+12	+18	+38	+38	+38	.....
W.	+14	+19	+26	+24	+23	+31
W.N.W.	+7	+8	+10	+6	0	.....
N.W.	+1	+4	+2	—6	—11	—17
N.N.W.	+1	+5	—10	—28	—41	.....

SOUTHERN UNITED STATES

WINTER

Surface Direction	Altitude, Feet					
	820	1,640	3,281	6,562	13,123	19,685
N.	+6	+6	—12	—48	—73	—67
N.N.E.	+11	+20	—20	—70	—88	—36
N.E.	+12	+14	+9	—125	—124	—120
E.N.E.	+16	+27	+98	+160	+204	+212
E.	+19	+47	+84	+129	+184	+176
E.S.E.	+20	+38	+64	+102	+126	+141
S.E.	+24	+38	+68	—89	+113	+114
S.S.E.	+13	+29	+50	—58	+112	.....
S.	+13	+27	+45	—70	+83	+96
S.S.W.	+11	+18	+34	—52	+73	+108
S.W.	+12	+19	+34	—47	+56	+73
W.S.W.	+7	+15	+25	—29	+46	.....
W.	+9	+11	+24	—25	+26	+30
W.N.W.	+15	+17	+18	—10	+2	—3
N.W.	+6	+5	—2	—15	—16	—11
N.N.W.	+2	+3	—7	—32	—45	.....

Average deviation of upper-air winds from surface direction.

shows the number of degrees surface winds will change with altitude, plus being to the right and minus being to the left.

58. From a study of the foregoing table, the following thumb rule may be drawn:

> *Winds over the North American Continent veer to the west with altitude, clockwise if the surface wind is southerly; counterclockwise if the surface wind is northerly.*

While above rule is derived from data obtained in the eastern United States, inference may be drawn concerning other sections.

59. In addition to change of direction with altitude, there is also a marked increase in velocity. Table 94 indicates the force of wind that may be expected at different altitudes for a given surface direction.

THUNDERSTORMS

60. When an area of low pressure is passing to the north of a given locality (in North America), the cool, dry northwest wind to the southwest of the storm center, will, by underrunning the lighter air, lift it and cause an upward draft of warm air in such a way that a cloud begins to form in the manner already explained. When the updraft of warm air has once started, the process continues with increasing rapidity and a thunderstorm, or series of thunderstorms will result.

61. Thunderstorms, as a rule, last only 4 or 5 hours, but due to their movement, the duration in one place seldom exceeds an hour or two. From a very small beginning, thunderstorms often increase to an area of 100 to 150 miles. Their general shape is more or less oblong, the front being 4 or 5 times the depth. They occur most frequently in the late summer afternoon.

TABLE 94

NORTHERN UNITED STATES

WINTER

Surface		Altitude (feet)					
Direction	Velocity	800	1,600	3,300	6,600	13,100	19,700
N.	10.1	5.6	6.4	7.4	12.0	24.3	33.8
N.N.E.	8.9	5.2	5.8	4.7	7.0	19.4	30.7
N.E.	8.5	6.2	7.8	6.4	8.0	18.5	25.1
E.N.E.	7.3	6.8	7.0	4.9	8.0	15.5	.....
E.	7.2	6.6	8.2	9.1	10.5	20.2	29.9
E.S.E.	8.2	6.4	7.4	8.5	9.9	15.5	25.1
S.E.	8.0	7.6	10.3	11.3	13.6	21.4	.....
S.S.E.	9.1	8.9	12.2	14.2	16.9	21.6	.....
S.	9.5	7.2	10.9	13.8	17.3	26.4	26.8
S.S.W.	9.7	8.5	12.0	14.6	17.5	25.1	24.3
S.W.	9.3	7.4	10.5	15.5	20.2	29.9	34.2
W.S.W.	9.3	7.0	9.5	12.8	19.8	33.6	.....
W.	10.7	7.6	10.1	13.8	20.4	33.0	42.5
W.N.W.	9.3	6.2	9.5	12.0	21.4	25.2	.....
N.W.	10.7	6.6	8.4	12.4	20.4	35.5	46.8
N.N.W.	10.9	6.4	8.4	10.5	16.9	31.3	.....
Calm	0.0	11.1	14.4	16.5	20.6	32.4	.....

SOUTHERN UNITED STATES

WINTER

Surface		Altitude (feet)					
Direction	Velocity	800	1,600	3,300	6,600	13,100	19,700
N.	8.5	6.0	9.0	10.7	15.9	31.1	40.0
N.N.E.	8.9	5.8	7.0	8.9	12.6	20.2	42.5
N.E.	8.2	5.2	6.8	7.6	14.0	26.6	35.7
E.N.E.	8.2	5.1	5.6	7.6	12.4	21.8	.....
E.	7.2	4.7	7.6	7.4	13.2	28.2	34.6
E.S.E.	7.2	6.6	10.9	14.8	17.3	.....	.....
S.E.	7.8	6.4	10.1	12.8	17.9	29.1	.....
S.S.E.	9.5	8.5	12.2	15.3	21.4	33.2	.....
S.	9.9	9.7	13.0	15.7	20.4	33.0	.....
S.S.W.	9.3	9.7	14.0	20.6	25.6	29.5	.....
S.W.	9.5	10.1	14.6	18.8	25.6	37.5	41.0
W.S.W.	8.9	8.9	12.4	17.3	24.7	41.6	.....
W.	10.5	8.2	12.0	16.3	23.9	37.9	.....
W.N.W	11.1	7.4	11.1	15.2	22.3	38.7	.....
N.W.	12.0	7.0	9.9	13.8	20.6	33.8	45.5
N.N.W.	10.5	5.6	7.4	13.8	21.0	38.1	.....
Calm	0.0	7.8	13.6	17.7	25.3	37.9	.....

Average increase in nautical miles per hour in winter of upper-air wind velocities above surface velocities.

62. The thunderstorm consists of a large cumulo-nimbus cloud, proceeded by a violent squall wind (see figure 95). The squall wind is the result of the rapidly descending cool air within, forcing up the warm air just in front of the storm. As such

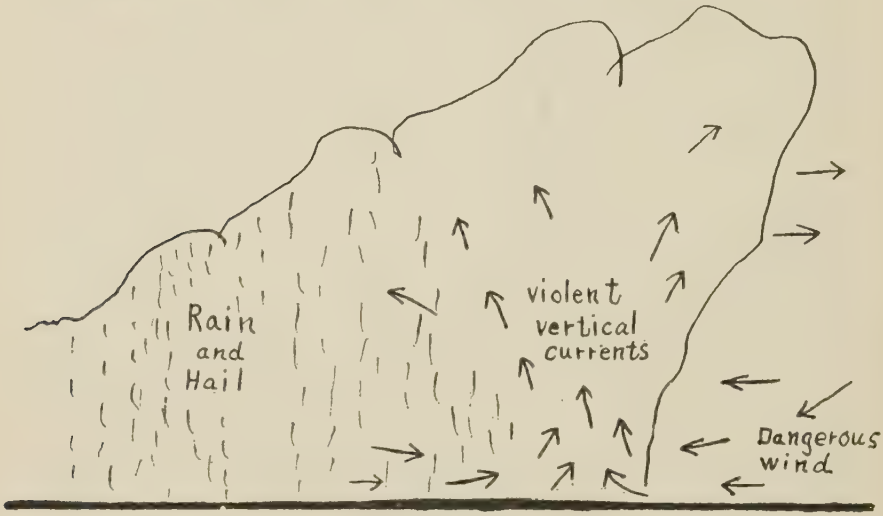


FIG. 95

storms usually occur along a line separating two masses of air, on the windshift line running in a general southwest direction from a well-developed low-pressure area, they are sometimes termed *Line Squalls*.

63. In back of the squall wind is a strong down current of cool air, followed very closely by heavy rain accompanied by terrific thunder and lightning.

Pilots are expressly warned not to attempt to fly through a thunderstorm with any type of aircraft whatsoever. The vertical currents in such a storm are so violent it is very doubtful if any aircraft could live in them.

64. In addition to the dangerous squall wind in front, and the violent vertical currents within, aircraft attempting to fly in the vicinity of a thunderstorm face the very grave possibility of being struck by lightning. A number of such cases have been recorded in recent years, mostly with fatal results.

65. Should a pilot find a thunderstorm in his path, he may, if the storm is small, fly around, or over it. *In either case, it must be given a wide berth.* If the storm area is so great that flying around it is not practicable, the only safe course is to turn back, and run from it until a safe field is located, and land and wait for the storm to pass.

HURRICANES

66. Storms, of which winds blow in a more or less circular motion, are known by special names in different localities. In the West Indies and southern United States they are known as hurricanes, while in China and the Indian Ocean, they are termed typhoons. They may, however, be classed under the general term of cyclones.

67. Cyclonic storms have a rotary or spiral motion around a center, or focus, and a progressive motion varying from 4 to 25 miles per hour. The peculiarity of the rotary motion of a cyclone is that in the northern hemisphere the wind is contrary to the hands of the watch, or, to the left, while in the southern hemisphere, the rotary wind is with the watch, or to the right. It will be noted that this is the characteristic low-pressure wind circulation.

68. Most of these storms striking the North American Continent originate in the tropics to the eastward of the West Indies. For some days, they travel along a path in a westerly direction at a very slow speed. As they advance, they seem to curve away

from the equator, and when reaching the 25th or 30th parallel of latitude, they generally curve still more and increase their progressive motion until they are moving in a northeast direction, when they travel out to sea and blow themselves out.

69. As previously stated, the progressive motion of the storm is from 4 to 25 miles per hour, but this progressive motion has no connection with the velocity of the wind. At its origin, the diameter of the storm is generally very small but increases as the storm works to the northward, reaching as much as 1,000 miles when about to break up. The most dangerous and destructive stage is when the storm area is still very small, when the wind often reaches 150 miles or more per hour. A case in point is the hurricane in Florida in 1926, the diameter of which was less than 30 miles when it passed over the State.

70. The little V-shaped cyclones of great violence that occasionally visit the central United States in the early spring and summer are known as *tornadoes*. Though these storms are of very small area—usually less than one-quarter of a mile in diameter and three-quarters of a mile high—they are particularly destructive and usually cause great damage. They are strictly local affairs, however, and of little interest to the aviator.

CLOUDS

71. The relation of cloud-forms of various kinds to weather, either existing or forecasted, is a matter of extreme importance, and those who are situated so that they are unable to receive weather forecasts, may use local cloud indications to good advantage. In the days of sailing ships, the master of such a vessel observed cloud indications as closely as he did the barometer.

72. Clouds are classed according to their appearance, there being four general forms: (1) Cirrus, (2) Cumulus, (3) Stratus, and

(4) Numbus. The following forms are arranged according to a general descending scale of altitude, observation having shown there are five main levels: Cirrus (highest), Cirro-Cumulus, Alto-Cumulus, Cumulus and Stratus (lowest). The abbreviation in parenthesis following the name of the particular form is the conventional symbol used in recording:

(1) Cirrus (Ci.).—Detached, delicate and fibrous-looking clouds, taking the form of feathers. Generally of a whitish color, sometimes arranged in belts across a portion of the sky, and seeming to converge toward one or two opposite points of the horizon. Height, about 5 to 6 miles.

(2) Cirro-Stratus (Ci.-S.).—A thin whitish sheet, at times completely covering the sky, and giving it a whitish appearance, or presenting a formation like a tangled web. This sheet often produces halos around the sun and moon. Height, about 5 to 6 miles.

(3) Cirro-Cumulus (Ci.-Cu.).—Small whitish masses, more or less globular in shape, arranged in groups and often in lines. This form of clouds is often referred to as "Mackerel Sky." Height, about 4 miles.

(4) Alto-Cumulus (A.-Cu.).—Rather large white or grayish masses, more or less globular in shape, partly shaded and arranged in groups or lines, and often so closely packed that their edges appear confused. They often spread themselves out in lines in one or two directions. Height, about 3 to 4 miles.

(5) Alto-Stratus (A.-S.).—A thick sheet of gray or bluish color, showing a brilliant patch in the vicinity of the sun or moon. At times the sheet is thin, showing the sun or moon, barely visible. This form goes through the same changes as Cirro-Stratus, but will not cause halos, though it may result in a coronæ. Variable height.

(6) Strato-Cumulus (S.-Cu.)—Large rolls or globular masses

of dark clouds, sometimes covering the whole sky and occasionally giving it a wavy appearance. As a rule, the layer of Strato-Cumulus is not very thick and patches of blue sky are often visible through intervening spaces. This form is distinguished from Nimbus by its rolled or globular appearance, and because it does not bring rain. Height about 1 mile.

(7) Nimbus (N.)—Rain Clouds.—A thick layer of dark clouds, without shape, and with ragged edges, from which rain or snow is generally falling. Through openings in this form an upper layer of Cirro-Stratus or Alto-Stratus will invariably be seen. If the Nimbus separates into shreds, or if small loose clouds are visible floating underneath a large Nimbus, they are called Francto-nimbus (Fr.-N.), commonly called "Scud" by mariners. Height, usually less than a mile.

(8) Cumulus (Cu.).—Thick wool packed clouds of which the upper surface is more or less dome-shaped and exhibits protuberances while the base is practically horizontal. When opposite the sun, the surfaces usually presented to the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, they give off deep shadows; when, on the other hand, the clouds are on the same side as the sun, they appear dark, with bright edges. True cumulus has clear and well defined upper and lower limits. It is often broken up by strong winds, and detached portions undergo continual changes. These detached portions may be distinguished as Francto-Cumulus (Fr.-Cu.). Height, about 1 mile or less.

(9) Cumulo-Nimbus (Cu.-N.).—Thunder Cloud; Shower Cloud. Heavy masses of clouds in the form of mountains, turrets or anvils, generally having a screen of fibrous appearance above called "false Cirrus," and a mass of clouds underneath similar to Nimbus. From the base, they are usually local showers of rain, snow or hail falling. Sometimes, the upper edges have

the compact form of cumulus, forming gigantic peaks, around which the "false Cirrus" floats. Sometimes, the edges separate into a fringe similar to that of the Cirrus cloud. The front of thunderclouds of wide extent frequently present the form of a large bow spread over a portion of the sky which is uniformly brighter in color.

(10) Stratus (S.).—A horizontal sheet of lifted fog. When broken up into irregular shreds by the wind, it may be distinguished by the name of Francto-Stratus (FR.-S.). Height, very low.

73. The character of the day with regard to clouds, as determined by the Weather Bureau, is divided into three groups. A day when the sky is three-tenths or less covered with clouds is recorded as *clear;* from four-tenths to seven-tenths as *partly cloudy;* and eight-tenths or more as *cloudy.*

74. Clouds are often termed the "Storm signals of the Sky." In every locality there is one direction of cloud motion that indicates fair weather and another that indicates foul weather. In hot summer weather, a coming thunderstorm may often be foretold several hours by the form and movement of the clouds. About the first indication of probable thunderstorms is when the sun in the morning, breaking through the clouds, seems scorching hot. In afternoon thunderstorm will probably follow.

75. Rainbows are caused by the refraction of the sun's rays on raindrops in the air, the center of the rainbow always being opposite the sun. A rainbow in the morning to the westward indicates showers will probably pass over the position of the observer during the day. A rainbow in the afternoon indicates the showers are to the eastward and passing on, so fair weather may be expected.

76. After clear pleasant weather, the first cloud signs of a probable change are light streaks, curls, or patches of white clouds

in the distance, gradually increasing, followed by an overcast, murky sky that grows into cloudiness. This appearance is an infallible sign of coming wind and rain. Usually, the higher and more distant the clouds seem to be, the slower will be the change.

77. High clouds crossing the sky in a direction different from the surface wind and lower clouds, indicate a coming change of surface wind to conform with their movement.

78. During a blow, light scud driving across heavy masses of clouds show wind and rain. Nasty weather will continue.

79. Light misty clouds forming or hanging around mountaintops should be watched closely. If they remain stationary, wind and rain are probable, but if they rise, or dissipate, clearing weather may be expected. Light delicate tints of color with soft looking clouds and blue sky indicate and accompany fine weather.

80. When the sun sets and the sky in the vicinity is a glowing red, with the sky overhead a bright blue, fine weather may be expected. But should the sunset be dark, followed by a whitish yellow extending to great heights, wet weather may be expected. A diffused brilliant white sunset indicates a coming blow.

81. When, after a fine day, the sun sets behind a heavy bank of clouds, and the barometer is falling, rain may be expected, within 24 hours.

82. A red sky at sunrise indicates probable nasty weather, while a soft gray sunrise indicates fine weather. A halo about the sun or moon indicates coming wet weather.

83. Fog is caused by a warm moist wind blowing over an area of relative cold water or land, and the movement of high clouds will often indicate the coming of this wind. For example, if, along the Atlantic seaboard, clouds at high altitudes are moving from the southeast to northwest, a warm and damp southeast

surface wind may be expected, causing fog, which usually lasts until there is a change of wind.

84. When the temperature of the earth falls below the dew point of the surrounding air, as it does shortly after sunset, the air releases some of its vapor in dew drops. On clear nights the temperature of the ground is rapidly cooled by radiation and the dew or saturation point soon is reached, while the air a few feet above the ground may still be several degrees warmer. Dew indicates fine weather. *No dew, after a very warm day, indicates coming rain.*

85. The following rules about foretelling weather by the appearance of the sky seem to deserve more critical study than is usually given the subject:

(a) A red sky at sunset presages fine weather, a red sky in the morning, bad weather and probable wind and rain, but, a gray sky in the morning indicates fine weather.

(b) Soft looking, delicate clouds indicate fine weather with light breezes.

(c) Heavy-edged, oily-looking clouds, wind; but a light, bright blue sky indicates fine weather. Generally speaking, the softer the clouds look the less wind, and the harder and more "greasy" and ragged, the stronger the wind.

(d) A bright yellow sky at sunset indicates wind; a pale yellow, rain.

(e) Seagulls flying over inland waters, or resting ashore, indicate a blow.

86. There are worlds of wisdom and truth in the following weather rhymes, and an experienced observer will often detect a coming storm some time beforehand by using only the information they contain:

1.

Red sky in the morning,
  Sailors take warning;
Red sky at night
  Sailors' delight.

2.

When the rain's before the wind,
  Topsail halliards you must tend,
When the wind's before the rain
  Soon you will make sail again.

3.

Long foretold, long last;
Small warning, soon past.

4.

Seagull, Seagull, sitting on the sand,
It's never good weather when you're on the land.

5.

Evening red and morning gray,
All are signs of a very fine day.

6.

The higher the clouds, the finer the weather.

7.

Mares tails and mackerel scales (clouds)
Make lofty ships carry low sails.

8.

A veering wind brings fair weather;
A backing wind brings foul weather.

REMARKS

87. At every well-regulated airport a careful record of existing weather should be kept. Observations should be made every two hours and the result carefully entered in a log book by some responsible person. With such reports constantly available, data from other stations, and a knowledge of atmospheric movements, the pilot is in a position to forecast the wind and weather to be expected on a proposed flight with a fair degree of accuracy.

88. The minimum meteorological equipment for efficient observation consists of (1) a barometer, (2) wet-bulb and dry-bulb thermometer, (3) wind vane and anemometer, and (4) a well-kept log book.

89. Observations should be made of (1) barometer, (2) temperature, both wet- and dry-bulb, (3) force and direction of the wind, (4) amount and kind of clouds together with direction of movement, (5) horizontal visibility, and (6) ceiling.

90. In addition to the equipment enumerated above, there should be a large bulletin board on which the most recent weather information from distant stations, as well as that of the local field, may be posted. A sample of such bulletin board is shown in Table 96.

91. In addition to the other methods of disseminating weather information, the United States Weather Bureau displays *storm warning flags* for the benefit of shipping at hundreds of observation stations situated on the Atlantic, Pacific and Great Lakes. A square red flag with a black square center indicates a storm of marked violence is expected. A red pennant or white pennant is displayed with the flag to indicate the direction of the coming wind; red for easterly (from N.E. to S.), white for westerly (from S.W. to N.). The pennant above the flag indicates the wind is expected from the northerly quadrants; below, from the

Time	Station	Weather	Ceiling	Visibility	Winds				Bar.	Ther.	Field	Remarks
					0	2,000	4,000	6,000				
10 A.M.	New York	Clear	....	Good	N.W.3	W.N.W.4	W.N.W.4	W.N.W.6	30.15	68	Good	
"	Boston	"	....	"	N.2	N.N.W.3	N.W.3	N.W.3	30.20	66	"	
"	Albany	Pt. Cloudy	....	"	W.3	S.W.3	W.4	W.4	30.10	66	"	
"	Buffalo	Overcast	2,000	Poor	S.2	S.2	S.W.3	S.W.3	29.80	72	"	Fog reported west
"	Cleveland	Rain	500	Poor	N.E.3	E.N.E.4	N.E.4	N.5	29.70	64	Bad	Field rough and muddy
"	Pittsburgh	Pt. Cloudy	....	Good	S.W.2	S.W.2	W.3	W.3	29.85	74	Fair	Hazy in mts. to west
"	Washington	Clear	....	"	N.W.1	N.W.2	W.N.W.2	N.W.3	30.15	71	Good	

TABLE 96

southerly quadrants. A red pennant displayed alone is a warning that a storm, dangerous for small craft only, is expected. See figure 97.

92. A warning system somewhat like the above could be employed to advantage on every large airport, and used in conjunc-

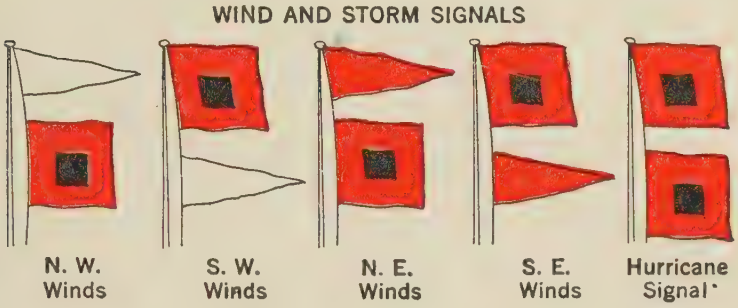


FIG. 97

tion with intelligent observation and forecasting, would probably save thousands of dollars damages resulting from unexpected storms over a period of years.

HIGH ALTITUDES

93. A word about mountain flying and high altitudes work in general might not be amiss here. It should be remembered that the higher above sea level a landing or take-off is made, the lighter will be the air, with a resulting all-around decrease in performance of the ship. As elevation increases, the landing speed increases, rate of climb is slower, and a much longer run is required to get off the ground.

94. As the wind always follows the contour of the ground, *there is always a down-current of air* to leeward of hills and mountains, and an up-current on the windward side. (See figure 98.) It is impossible to climb in a strong down-current and the controls may

become sloppy, even with the ship flying level. Particular care must be exercised on a high altitude take-off, and landing, too, as at times the air seems to go out from under the ship, allowing it to suddenly sink ten or twenty feet.

95. In flying over mountain tops, it is well to cross them at an angle. Then, if a bad down-current is suddenly experienced, the

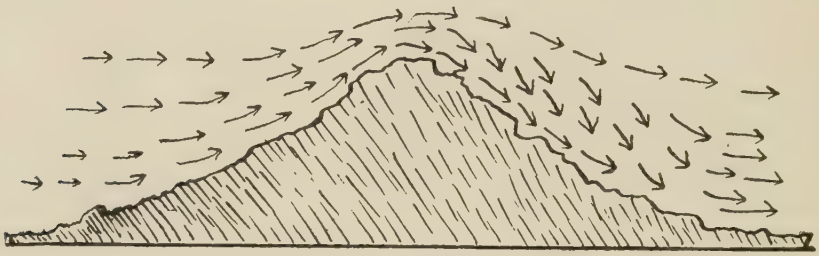


FIG. 98

ship may be nosed down and turned toward safety without danger of hitting the ground.

96. Inexperienced pilots about to land on a strange field should also be particularly careful of unexpected up- or down-drafts, caused by sloping or rolling ground, or where one side of a landing field drops off and is appreciably lower than the field itself. With a gentle breeze only a slight bump will be noticeable, but the stronger the wind, the stronger the down- or up-draft will be. Such a condition is a real hazard to a ship standing in for a slow landing.

BUMPS

97. Heat bumps generally begin to manifest themselves soon after sunrise, especially in summer. To begin with they are usually within a few hundred feet of the ground, but gradually ascend until noon when they may reach 2,000 feet or 3,000 feet. A partly cloudy sky on a warm day causing alternate patches of sunshine and shade will cause numerous up- and down-drafts,

usually resulting in a bump day. Bumps may be expected when passing over inland sheets of water, from a dry to a green field, or in fact, any place or time when ground conditions cause an up- or down-current of air. Bumps are seldom found when flying over the sea.

CHAPTER X

FIRST-AID

1. The immediate treatment of wounds in general is extremely simple, and by immediate treatment serious complications are often avoided. In case of serious accident, in order to save life, some one on the spot must render first-aid and keep the injured person living until expert medical aid arrives. It is the duty of every citizen to familiarize himself with the details of first-aid so he may be able to give efficient help to an injured fellow being.

FRACTURES

2. Perhaps the most common injury met with in flying is fractured bones. Fractures are divided into classes, simple and compound. Simple fractures are those which are beneath the unbroken skin. Compound fractures have external wounds communicating with the break.

3. In fracture cases, the injured person should be attended on the spot where the injury occurred, especially if the fracture happens to be a lower extremity. The injured parts must be handled with extreme gentleness; by rough handling a simple fracture may be converted into a compound one, especially where the bone is just under the skin, like the shin-bone or collar-bone.

4. Before attempting to move an injured person, broken bones should be located and first-aid given. Clothing must be removed or cut away from the parts that appear injured and a careful examination made. If there be a compound fracture, surface wounds and a probable hemorrhage will be present. If the

injury involves the great blood vessels, *the victim will probably die immediately, unless some one checks the flow of blood.* A simple fracture may be located by immediate swelling, severe pain and deformity at the seat of injury; unnatural mobility, where no mobility should exist, and a grating sensation where the ends of the bone move against each other.

5. In rendering first-aid to persons having broken bones, the first objective should be to prevent further injury. The injured part should not be handled, beyond what is necessary for diagnosis, until all splints and bandages are ready. Then, bring the bones into their relative positions as follows: grasp the limb above and below the break and make gentle extension and counter extension in normal line of the bone, which should cause little or no pain if carefully done. When in proper line, fix the limb in this position with splints and bandages.

6. Emergency splints should be more or less rigid supports, so applied as to hold the injured part in its normal position. Many articles in daily use, and others that can always be found around the field can be used for this purpose. For instance, broom handles, stockings filled with sand, grass rolled in a newspaper, or a couple of pieces of board can be used. The opposite leg can be used as a splint for the injured one, and in case the injury be an arm, it can be splinted against the chest by snugly binding it there with bandages made from any available material. The principal requirement is to obtain splints of material sufficiently stiff to keep the parts in position. Splints should, if possible, be as wide as the limb to which they are to be applied, and well padded with some soft material, such as clothing, towels or other cloth.

7. To apply splints to a broken leg or arm really requires two persons, though one may manage if absolutely necessary. One person gently lifts the injured part and, while supporting it with

one hand, steadily pulls in the line of the injured bone. When the bone is in line, the second person applies the splints, one on each side of the limb, and secures them in position by tying about them, above and below the injury. Strips of fabric, belts, suspenders or strips of clothing may be used to secure the splints in place. All knots should be tied over the splints and not over the exposed limb. Care must be taken not to make the splints so tight as to impede the circulation. The general rule that an injured part should be elevated holds good with broken bones. If

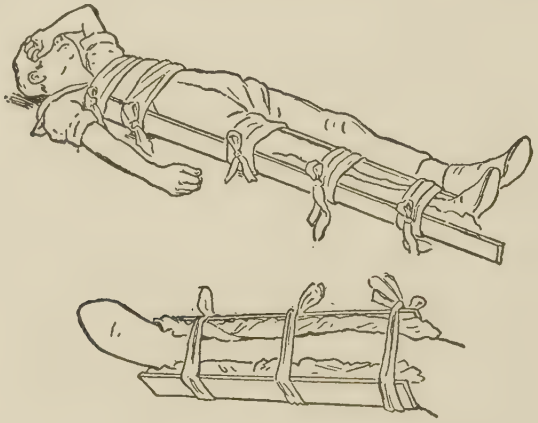


FIG. 99

an injured limb is splinted and then allowed to hang down, swelling will follow rapidly and circulation may be dangerously cut off. (See figure 99.)

8. A compound fracture is splinted in the same manner as a simple one. The principal danger in this sort of an injury is death from loss of blood, and wound-poisoning. Before the splints are applied the hemorrhage must be stopped. The wound must not be touched with the fingers unless absolutely necessary to stop the injured person from bleeding to death.

9. A fractured jaw may be taken care of by tying a bandage under the chin and around the top of the head. A fractured

skull is a job for the doctor and there is very little that can be done. Dress the wound and stop the flow of blood.

CHECKING A HEMORRHAGE

10. When the blood spurts in jets, or flows very freely from the wound of a compound fracture, or from any other wound or deep cut, one of the great vessels has been ruptured and *the wounded man is bleeding to death.* To check the hemorrhage, the great vessel supplying the injured part must immediately be pressed against the bone with the fingers, and a tourniquet applied as soon as possible. Finger pressure cannot be kept up very long and in order to save life it may become necessary, *in rare cases,* to put the finger or thumb directly into the wound in order to compress the bleeding vessel. *Under no other circumstances should unclean fingers come in contact with the wound.*

11. In order to control a hemorrhage properly, it is necessary to know the location of but four great blood vessels. In figure 100, arrow 1 points to the artery which supplies the head with blood. Arrow 2 points to the artery behind the middle of the collar-bone, which continues into the arm and becomes 3, supplying the arm and hand. Arrow 4 points to the artery which supplies the feet and legs. Every one should study the pulsation of these vessels in their own bodies in order to become familiar with their location, and to determine the amount of pressure necessary to arrest the blood flow.

12. A tourniquet may be constructed with any strip of cloth of sufficient length to encircle the limb. A small stone, nut, pocket-knife, or some other object should be placed directly over the vessel and pressed in by twisting the tourniquet with a stick, as shown in figure 101. If the wound be in the lower limb, place the tourniquet as high as possible with the stone between the legs.

For a wound in the arm, the artery to be compressed is located about two inches from the armpit on the inside. A scalp wound should be bandaged tightly. If the hemorrhage continues, com-

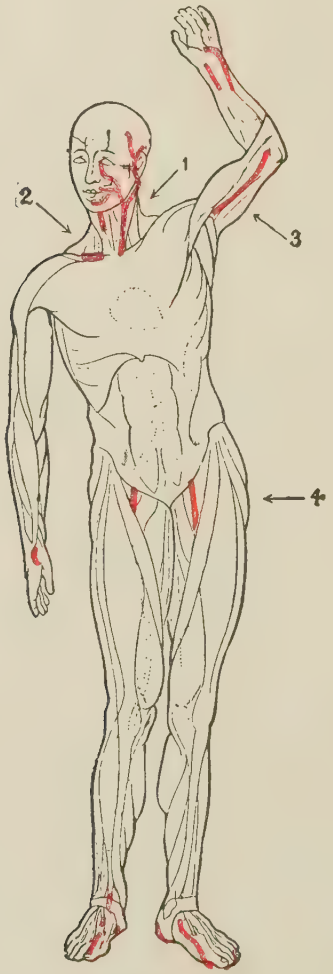


FIG. 100

press the artery leading to the head *with the fingers*. This artery is located on the side of the neck, in line with the ear, and pressure should be applied just above the collar-bone.

13. For an internal hemorrhage, about the only first-aid that can be given is a tight bandage over the wound. In all cases keep the injured person as quiet as possible and thus secure a condition of rest for the bleeding parts. In cases of hemorrhage where there is no fracture, or where the condition of the fracture makes

Fig. 101

it possible, elevate the wound and get it above the heart, if possible.

14. The tourniquet must not be left on indefinitely, but should be loosened a little every 15 or 20 minutes to allow blood to circulate to the other parts; if the hemorrhage begins again, it may be tightened up. By carefully loosening the constriction in this way, very little additional blood is lost and there is much less danger of gangrene setting in later on.

SUFFOCATION AND SHOCK

15. Victims of gas suffocation and the apparently drowned, are suffering not only from suffocation, but usually from exhaustion caused by struggling, shock from fright, and cold. Persons unconscious from fright alone suffer from shock only. All such cases should be removed to the open air at once and clothing

loosened. If breathing is suspended, or very feeble, artificial respiration should be given. In gas suffocation and shock from fright, it is not necessary to clear the mouth as in the case of drowning accidents, but care must be taken that the tongue does not fall back so its base will close the breathing passage.

16. While drowning accidents are far from common in aviation, the artificial respiration given is the same as that used for the more common accidents. The following method of resuscitation of the apparently drowned has been accepted in marine circles as more or less of a standard, and has frequently been employed in all sorts of suffocation cases with gratifying results. The method was developed for application by a single person, but additional persons can assist and thereby make results doubly sure. In all cases of death from suffocation, artificial respiration should be continued until the victim has been pronounced dead by competent medical authority. Several cases are on record where life has been saved, when results of resuscitation did not manifest themselves until after more than two hours of constant application.

17. A vigorous attempt to revive the apparently drowned person should be made in the following manner:

First: Remove the patient's shirt and undershirt; lay patient on his face with his arms extended upwards; straddle the patient, facing his head, and clasp hands under his stomach; raise his abdomen from the ground and hold in this position for several seconds while water is draining from the lungs and air-passage.

Second: Turn patient on his back quickly, placing a rolled shirt or coat under his shoulders, and thoroughly wipe out his mouth and nose. Pull the tongue well forward and tie it against the lower teeth by passing a string over it and under the chin.

Third: Place patient on his stomach, with face turned to one side; kneel beside him and place the palms of your hands on the

sides of his back along the lower ribs; lean forward gradually and bring the weight of your body on the hands, thus forcing the air out of the lungs. Release the pressure quickly and return to the first position. The first motion should occupy about 3 seconds, and, after returning to the original position, wait 2 seconds and repeat the operation; thus, there will be about 12 respirations per minute.

Fourth: All wet clothing should be removed while artificial respiration is being given and the body and limbs should be rubbed toward the heart. Warm blankets, hot-water bottles, hot sand or bricks should be applied to restore bodily warmth.

Fifth: Do not give stimulants until patient can swallow. Do not remove him or stop rubbing until he is fully conscious and breathing naturally.

Sixth: As soon as a suffocated patient regains consciousness, reassure him and keep him quiet. This is very important. As soon as full consciousness and natural breathing are restored, the patient must have complete quiet and rest.

BURNS AND SCALDS

18. There are three degrees of burns: first degree, a mere reddening of the skin; second degree, the formation of blisters (the first and second degrees are not followed by scarring and unless one-sixth of the body surface is involved recovery may be expected); the third degree is where the tissues are charred and destroyed.

19. Burns of the second and third degree usually result in a severe shock to the system, which is shown by a cold, moist skin, shallow breathing and weak pulse. If the patient shows these symptoms, he should be treated for shock first and for burns afterward when reaction sets in.

20. To treat the injury, remove the clothing carefully, seeing that no blisters are broken. It may be necessary to cut the clothing away and, if parts stick, soak them in oil. Dress only one part at a time. In extensive burns, a bed sheet, well greased, wrapped about the entire person makes an excellent temporary dressing.

21. To dress burns, proceed as follows: apply pieces of lint soaked in solution of common washing-soda (two tablespoonfuls to a pint of water). Boracic acid ointment (10 per cent) spread on lint and applied to the burn makes a simple and efficient temporary dressing. Strong solutions and powders are dangerous in the hands of the inexperienced and should be avoided.

22. A normal salt-solution, made by dissolving a teaspoonful of common table salt in a pint of water bringing it to a boil and letting it cool, is the only solution that should be used to cleanse burns. In fact, salt-solution is the best obtainable emergency solution for cleansing wounds of all kinds. If a piece of paraffin is obtainable, it will make the best possible dressing. Melt the paraffin and cover the entire burn. When paraffin has cooled, cover it with a thin layer of absorbent cotton or bandage.

23. Acid burns should first be flushed with water. Then wash with a common solution of washing-soda and finally treat as an ordinary burn. Sunburn should be treated in the same manner as other burns. Limewater, with the addition of 2 drops of carbolic acid to the ounce, is a very soothing application.

FREEZING

24. In case of a person apparently dead from exposure to the cold, rub the body and limbs vigorously, apply heat externally and do artificial respiration. When circulation is restored, patient

becomes conscious, color returns, heart beats reappear and breathing starts. Give hot drinks at intervals of 15 minutes.

25. Efforts to revive the apparently dead should be continued at least two hours, unless competent medical authority pronounces the case hopeless. If the person has long been exposed to extreme cold, there will follow a depression of vitality which requires most cautious treatment.

26. Bodily warmth should be restored by surrounding the patient with heated blankets, or exposing him before an open fire. If a bath can be given, immerse the patient in warm water and gradually increase the temperature until it is as hot as he can stand it. Alcoholic stimulants may be given but in moderation. One tablespoonful every half hour is quite sufficient.

27. In cases where the effects of the cold are frostbites, the warmth and circulation must be restored gradually to the affected part. If the case is mild, rub the part lightly and apply cloths wrung out in cold water. If it be a severe case and the parts are still dead, rub with snow or ice-water, and, as life returns, with water not so cold. The rubbing must be most carefully done as any roughness is likely to increase the damage. The change from cold to natural warmth may occur of itself. If brought about too quickly, or, if it does not come at all, gangrene results.

28. Gangrene is indicated by the skin turning black and blistering or scaling off. When this condition is present, do not use friction. Protect the part with warm melted paraffin. Avoid a tight bandage.

SPRAINS AND DISLOCATIONS

29. The straining or tearing of the ligaments and capsule which surround a joint, results in pain, heat and swelling around the

injury, followed by discolored skin. The injured part should be put at complete rest by elevation and support on a pillow or pad and apply cold applications. If pain is severe and cold applications cannot be tolerated, bathe the joint in water as hot as can be borne comfortably. Later, a snug bandage should be applied until a doctor can examine the injury, when he will probably strap it.

30. A dislocation is the displacement of the end of a bone which enters into the formation of a joint. Dislocated bones usually lie away from the body and cannot be brought to the side so as to parallel the body. Any attempt to move the bone results in severe pain. The danger of increasing the injury when attempting first-aid for a dislocated bone is greater than the danger of awaiting the doctor's arrival. The only thing to be done is to put the parts in a position easiest to the patient and surround the joint with cool, wet cloths.

REMARKS

31. Every person connected with aviation should know how to efficiently recognize and (1) check a hemorrhage, (2) handle a compound fracture case, (3) splint a simple or compound fracture when medical aid is not immediately available, (4) give artificial respiration, and (5) handle a person suffering from severe burns.

32. The purpose of first-aid is not to make every man his own doctor, and thus eliminate the necessity for outside medical aid. In all cases of serious accident a physician should be summoned immediately; in fact, it is a good plan to call two or three doctors so to be sure of getting at least one in a hurry. In the interval between the time of the accident and the arrival of a doctor, those present should make use of their first-aid knowledge so the

victim will at least have a fighting chance. Most any doctor can recall a number of fatal cases where, had intelligent first-aid been rendered at the time of the accident, the patient would probably have survived.

CHAPTER XI

AIR COMMERCE REGULATIONS

1. Many accidents grow out of careless disregard for Air Commerce Regulations, or out of plain ignorance of them or their meaning. A pilot, who will not study the regulations and keep refreshing his memory, will find no short-cut method to help him out. It must be remembered that these regulations are the result of many years' practical experience and are in effect to prevent a repetition of some accident. They should be looked upon, not so much as the law, but more as a safety agreement between all persons who fly or are connected with aviation; as a set of rules by which the entire industry has agreed to abide. The fellow who violates any section of the regulations is a cheat, as his very presence in aviation is an admission that he has agreed to play the game according to the rules, which he has failed to do. There is no room in any business for a cheat, and much less in aviation, where self-satisfied ignoramuses may cause the death of innocent law-abiding persons.

2. The Air Commerce Regulations are given here just as issued by the Department of Commerce. No attempt will be made to elaborate or comment, and if a man has not enough intelligence to understand their full meaning, he had best stay out of the air. All newcomers in aviation are urged to study these important but simple regulations and abide by them, word for word. *Older members* of the profession should read them through occasionally; make it the quarterly office.

REGULATIONS

Licensing of Aircraft

Section 1. Licensing Law.

"'Air commerce' means transportation in whole or in part by aircraft of persons or property for hire, navigation of aircraft in furtherance of a business, or navigation of aircraft from one place to another for operation in the conduct of a business." (Sec. 1, air commerce act of 1926.)

"'Interstate or foreign air commerce' means air commerce between any State, Territory, or possession, or the District of Columbia, and any place outside thereof; or between points within the same State, Territory, or possession, or the District of Columbia, but through the air space over any place outside thereof, or wholly within the air space over any Territory or possession, or the District of Columbia." (Sec. 1.)

*"The Secretary of Commerce shall, by regulation * * * provide for the granting of registration to aircraft eligible for registration, if the owner requests such registration * * *." (Sec. 3 (a).)*

*"It shall be unlawful * * * to navigate any aircraft * * * in interstate or foreign air commerce unless such aircraft is registered as an aircraft of the United States." (Sec. 11 (a) (2).)*

*"To navigate any aircraft registered as an aircraft of the United States * * * without an aircraft certificate, or in violation of the terms of any such certificate." (Sec. 11 (a) (3).)*

*"Any person who (1) violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of $500 * * *." (Sec. 11 (b).)*

Aircraft means "any contrivance now known or hereafter invented, used, or designed for navigation of or flight in the air, except a parachute or other contrivance designed for such navi-

gation but used primarily as safety equipment." (Sec. 9 (c).) Aircraft of the United States means "any aircraft registered" under the air commerce act. (Sec. 9 (f).)

Sec. 2. Application of the Law.

Aircraft must be licensed before engaging in—

(*A*) *Carrying persons or property for hire, or the United States mails*—

(1) Between two or more States, or to or from foreign countries, as from Chicago to Cleveland, Ohio, or from New York to Portland, Me., to Montreal, Canada.

(2) Between two points in one State if a part of the flight is over another State, as from Buffalo to New York via Susquehanna, Pennsylvania; or from Buffalo, thence over any part of Pennsylvania, and thence back to Buffalo.

(3) Between two points in one State if it is a part of a through carriage between points in different States, or countries, as from Los Angeles to San Francisco, California, as a part of the carriage between Los Angeles and Seattle, Washington, or from San Antonio, Texas, to Laredo, Texas, as a part of the carriage between San Antonio and Monterey, Mexico.

(4) Within the air space over the District of Columbia, or any Territory or possession of the United States.

(*B*) *Aircraft used solely for pleasure or noncommercial purposes need not be licensed, although engaged in flying between States,* but, at the option of the owner, may be licensed, in which event it must observe all the requirements of licensed aircraft. *Whether licensed or not, all aircraft must display the assigned identification mark.*

Sec. 3. Aircraft Belonging to the United States.

Aircraft belonging to the United States will be licensed by the Secretary of Commerce if the operating agency so requests.

Sec. 4. Aircraft Belonging to States, etc.

Aircraft belonging to States, Territories, or possessions of the United States, or to political subdivisions thereof, will be licensed by the Secretary of Commerce and rated as to airworthiness in the same manner as other craft if request for licensing is made and such aircraft are used exclusively in the governmental service.

Sec. 5. Foreign Aircraft.

(*A*) Where civil aircraft of the United States are permitted to fly in or over a foreign country without registration and rating and licensing of their airmen, the aircraft of such foreign country, not a part of its armed forces, and the airmen serving in connection therewith, may operate without a license in the territory over which the United States has jurisdiction. Such foreign aircraft shall not engage in interstate or intrastate air commerce and must observe the air-traffic rules.

(*B*) Aircraft owned by resident aliens will be granted identification marks but shall not engage in interstate or intrastate air commerce.

(*C*) Registered aircraft of the United States shall not be flown or operated in air commerce in the United States or its possessions, by, or in behalf of any individual, partnership, firm, or corporation not eligible to license for such registered aircraft.

Sec. 6. Requisites of Licensing and Registration.

An aircraft, to be entitled to license and registry, must be airworthy and equipped in accordance with requirements of the Secretary of Commerce and owned by—

(*A*) A citizen of the United States and not registered under the laws of any foreign country; or

(*B*) A partnership of which each member is a citizen of the United States; or

(*C*) A corporation organized under the laws of the United States, a State, Territory, or possession of the United States, and of which the president and at least two-thirds of the directors or managing officers are citizens of the United States, and of which at least 51 per cent of the voting interest in the corporation is controlled by citizens of the United States; or

(*D*) The Government of the United States, a State, Territory, or possession, or a political subdivision thereof.

Sec. 7. Registration, Meaning of.

Registration means entry of licensed aircraft in an official license registry of the Secretary of Commerce as aircraft of the United States. Unlicensed aircraft, though entered of record for purposes of identification as required by law, are not registered aircraft within the meaning of these regulations.

Sec. 8. Airworthiness, Law of.

*"The Secretary of Commerce shall by regulation * * * provide for the rating of aircraft of the United States as to their airworthiness * * *. The Secretary may, from time to time, rerate aircraft as to their airworthiness upon the basis of information obtained under this subdivision."* (*Sec. 3 (b).*)

*"It shall be unlawful * * * to navigate any aircraft registered as an aircraft of the United States without an aircraft certificate or in violation of the terms of any such certificate."* (*Sec. 11 (a) (3).*)

*"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of $500."* (*Sec. 11 (b).*)

Sec. 9. Airworthiness, Meaning of.

Airworthiness means a condition meeting the minimum aircraft requirements as set forth herein.

Sec. 10. Airworthiness Requirements.

(*A*) AIRWORTHINESS FACTORS.—In determining the airworthiness of airplanes the following factors are taken into consideration:

(1) The structural strength of wings, ailerons, tail surfaces, fuselage including engine mount, fittings, control system, and landing gear, as shown by stress analyses.

(2) Cockpit, cabin, and control arrangements.

(3) Power plant and power-plant installation.

(4) Equipment and instruments.

(5) Propellers.

(6) Design of fittings.

(7) Materials and workmanship.

(8) Flying characteristics and qualities.

Certain of these items may be demonstrated by theoretical analyses and drawings, others by visual inspection, and others by tests.

(*B*) LOAD-FACTOR REQUIREMENTS.—The load-factor requirements for the structural members of an airplane shall be determined as follows:

(1) *Flying conditions.*—Figure 1 hereof, and hereby made a part of these regulations, shall be used to determine the load factors for the high angle of attack condition of landplanes and float-type seaplanes. Reference shall be made to it and the factor obtained for the appropriate weight and horsepower loading, the factors for gross weights which lie between 2,500 and 12,500 pounds being determined by interpolation between the appropriate curves. For multi-engined airplanes the horsepower to be used for computing the loading in pounds per horsepower shall be that necessary to maintain level flight with full load at sea level. For flying boats and amphibians of 5,000 pounds gross weight or less the factor for 5,000 pounds shall be used; for

gross weights in excess of 5,000 pounds the factors shall be those indicated by the actual weight and power loading.

In the low angle of attack condition the load factor shall be 65

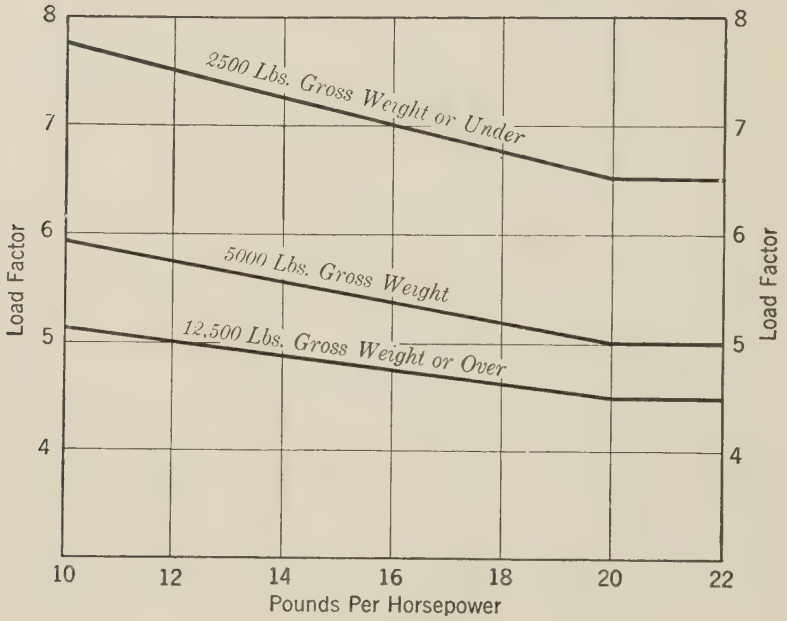


FIG. 1.—*Load factors—High angle of attack*

For flying boats and amphibians of 5,000 pounds gross weight or less, use the 5,000-pound gross weight factors. Horsepower loading shall be based on rated engine horsepower except that for multi-engined airplanes the horsepower shall be taken as that necessary to maintain level flight with full load.

NOTE.—It is to be noted that the load factors given in this chart are not sufficiently high to conform to the international requirements throughout the entire range of horsepower loading. Manufacturers designing airplanes for export should take into account the load factors and design requirements of the country to which the airplane is to be exported.

per cent of the high angle of attack factor, but in no case less than 3.

For the inverted-flight and nose-dive conditions the load factor shall be 40 per cent of the high angle of attack factor, but in no case less than 2.

(2) *Landing conditions.*—The load-factor requirements for landing conditions shall be obtained from Table 1. If the landing gear is designed to absorb landing shocks by the flow of a liquid through an orifice (the oleo or oleo-pneumatic type), the design load factors for the landing gear may be reduced by not more than 25 per cent from those shown in Table 1, but suitable provision shall be made to carry taxiing shocks after the absorber has been forced to the full extent of its travel.

For float seaplanes the floats and the members to which they are attached, including the "carry-through" tubes in the fuselage, shall be designed for a factor in landing of 8.0.

The shock absorber in the chassis of a landplane or amphibian shall be designed to absorb the energy generated by a free drop of the airplane from the height specified in Table 1 without subjecting the airplane or landing gear to forces greater than those corresponding to the load factors for landing.

The tail-skid shock absorber shall be designed to resist a free drop in the three-point landing attitude equal to that shown in Table 1 without imposing loads on the tail skid or fuselage greater than those corresponding to the load factors for landing.

(3) *Tail surfaces and ailerons.*—Tail surfaces and ailerons shall be designed to withstand the loads specified in Table 1.

TABLE 1

Class	Factor for landing conditions	Height of free drop for design of shock absorber (inches)	Loads per square foot on ailerons and horizontal tail surfaces	Vertical tail surfaces
2,500-pound or less...	6.5	24	30	75 per cent of load required on horizontal surfaces.
5,000-pound	5.5	22	25	
12,500-pound	5.0	20	20	
12,500-pound or over.	4.5	18	20	

(4) *Seaplane floats and boat hulls.*—Flying-boat and seaplane-float bottoms shall be designed to withstand, without permanent set, the following loads:

(*a*) Eight pounds per square inch over that portion of the hull lying between the first step and a section 25 per cent of the distance from the step to the bow; (*b*) 4 pounds per square inch from that section to a section at 75 per cent of the distance from the step to the bow; (*c*) 4 pounds per square inch between the first and second steps; and (*d*) 4 pounds per square inch between the rear step and a section 50 per cent of the distance to the stern. If but one step is used, this load shall extend over that portion of the hull between the step and a section 50 per cent of the distance from the step to the stern.

The submerged displacement of the main floats shall be at least 190 per cent of the full load of the airplane. Main floats shall be divided into at least five water-tight compartments.

In designing the bow portion of the hull due attention must be paid to the effect of striking floating objects.

(*C*) Control system.—The control system shall be designed to withstand a load of at least 300 pounds in a fore-and-aft direction and 150 pounds in a lateral direction applied at the grip on a stick control; on a wheel control it shall withstand at least 300 pounds in a fore-and-aft direction applied at the center of the wheel and a couple equal to 125 pounds times the diameter of the wheel applied tangent to the rim of the wheel. The rudder controls shall be designed to withstand a load of not less than 300 pounds applied at the point of contact with the foot. On airplanes having a gross weight of 1,000 pounds or less, two-thirds of the above values may be used. In any case, the strength of the control system shall be sufficient to withstand loads on the control surfaces 25 per cent greater than those specified in Table 1 for the design of the surfaces. The entire control system shall

be so designed that the rudder, elevators, ailerons, and other movable parts thereof will not jam, and, if necessary, control stops shall be provided to prevent it.

Dual controls on airplanes carrying passengers for hire shall be so constructed or arranged as to prevent passengers from interfering with the course of flight of the airplane.

(*D*) CONSTRUCTION OF COCKPIT AND CABIN.—The cockpit or cabin shall be constructed to afford suitable ventilation, adequate vision to pilot under normal flying requirements, and reasonable protection to pilot and passengers against possible propeller breakage.

Closed cabins of airplanes carrying passengers for hire shall have not less than two exits, affording maximum ease of operation. One of such exits may be an emergency exit, in which case the size, location, and method of operation shall be subject to the approval of the Secretary of Commerce.

(*E*) POWER-PLANT REQUIREMENTS. — Engines which have passed the regular endurance tests of the United States Army Air Corps or the United States Navy Bureau of Aeronautics will be approved by the Department of Commerce. Other engines submitted for approval will be tested by the Department of Commerce at the Bureau of Standards.

The log shall include the following:

Piston displacement, compression ratio, type of ignition, carburetor and spark plugs; barometric reading and complete list of instruments and apparatus used for the test. The length of brake arm and gear ratio if propeller is geared shall also be given. The test shall be such as to develop the following data:

(1) A plot of power developed at various revolutions per minute with the throttle wide open.

(2) Record of log showing readings, at approximately 30-minute intervals, of—

(*a*) Revolutions per minute.

(*b*) Brake load in pounds.

(*c*) Oil pressure and temperatures.

(*d*) Water temperatures.

(*e*) Air temperature at carburetor intake.

(*f*) Blast velocity.

(*g*) Maximum cylinder temperature, head and barrel.

(*h*) Manifold depression in inches of mercury.

(*i*) Fuel time in seconds for at least 5 pounds.

(*j*) Oil in pounds.

(*k*) Brake horsepower.

(*l*) Remarks, including breakages and replacements.

The 50-hour endurance test shall be run in 10 five-hour periods. During the first 5 hours the engine shall be run with the throttle wide open, the speed being at least equal to the rated speed and the power being at least 10 per cent in excess of the rated power. During the remaining 45 hours the engine shall be run at approximately rated speed and the horsepower developed should at no time be less than the rated horsepower.

(3) Photographs showing set-up of the testing apparatus used and of any parts which failed or showed excessive wear.

(4) List of instruments and apparatus used.

(5) After completion of the test, and a complete tear down, a report of detailed inspection of engine parts, particular attention to be paid to excessive wear and signs of failure.

An engine, after successfully passing the required block tests, shall be installed in an airplane and given actual service tests.

A newly constructed engine of a type and design which has been tested in accordance with the provisions hereof must not be installed in an airplane until bench tested for at least two hours, during at least one-half hour of which the engine must be run at full throttle.

An engine which has been in storage for more than one year must not be installed in an airplane until it has been reconditioned in accordance with accepted safety practices.

A reconditioned engine must be run for at least 20 minutes at full throttle before it shall be used in propelling registered aircraft carrying persons or property for hire.

(*F*) Power-plant installation.—With water-cooled engine installation a fire wall of terneplate, galvanized steel, asbestos-aluminum combination, or equivalent thereof, shall be installed, insulating the engine section from other parts of the airplane. Aluminum or aluminum-alloy fire walls will be satisfactory for air-cooled engine installations. Openings made in the fire wall to allow the passage of pipes or wires shall be provided with suitable glands or gaskets.

Carburetor air intakes must open outside the cowling and shall be suitably drained. Exhaust manifolds shall be installed outside of cowling unless specifically authorized by the Secretary of Commerce.

Throttle-control and ignition switches on multi-engined airplanes shall be arranged to permit separate and simultaneous control.

Suitable ventilation shall be provided for the engine compartments.

Air-pressure gasoline-feed systems shall not be used without approval of the department.

Airplanes carrying passengers for hire shall have installed an adequate reserve-gasoline supply tank, or satisfactory, reliable apparatus for indicating to the pilot a depletion of the gasoline supply.

(*G*) Propellers.—Propellers which satisfy any of the following requirements will be acceptable:

LIBRARY
College of St. Scholastica

(1) Designs from which a propeller has been flown for 150 hours without failure on an engine of equal or greater power than that for which the approved rating is sought. Affidavit specifying the number of hours of satisfactory service on a given engine and aircraft, the name of the operator, operating firm, and other pertinent data shall be forwarded to the Secretary of Commerce, together with detailed drawings of the propeller.

(2) Designs which embody only minor modifications from propellers accepted and used by the United States Army or Navy, the contractor to state specifically the departure, if any, from Government design.

(3) Designs which are approved designs, cut down to smaller diameters without reduction of the maximum ordinates, except in the immediate neighborhood of the tip.

Propellers not in accordance with the foregoing shall be tested in the manner prescribed by the Secretary of Commerce.

Propellers must have a ground clearance of at least 6 inches when the airplane is in a horizontal position.

On multi-engined airplanes a clearance of at least 1 inch must be provided between the tips of the propellers and the fuselage or any part of the structure.

The seats shall be so arranged that pilots and passengers are more than 12 inches forward or aft of the propeller disks. Surfaces near the propeller tips must be suitably stiffened against vibration.

(*H*) Performance requirements.—(1) The following flight tests with the design gross load shall be required:

(*a*) General flight, which includes a half-hour flight test with full load, to determine stability.

(*b*) General maneuverability, which includes, among other things, a flight with full load around two pylons or buoys 1,500 feet apart, making five successive figure 8's at 1,000 feet without

varying more than 200 feet in height in a radius not to exceed the following:

Five hundred feet for airplanes of full load not in excess of 5,000 pounds.

Seven hundred and fifty feet for airplanes of full load over 5,000 pounds and not in excess of 12,500 pounds.

One thousand feet for all other airplanes.

(2) The landing speed shall not exceed 60 miles per hour when the airplane is provided with a braking device, or 50 miles per hour when not so provided. Landing speed may be assumed equal to the calculated stalling speed. If the foregoing landing speeds are exceeded, the following flight tests with full load shall be required:

(*a*) Take-off within 1,500 feet.

(*b*) Climb at least 250 feet the first minute after taking off.

(*c*) Land, coming to a full stop without external aid, within 1,000 feet from the point where the landing gear first touches the landing area.

(3) Tests are to be calculated upon the basis of air of a specific weight of 0.07635 and still-air conditions.

(4) The applicant must provide the person to make the flight tests, but an inspector from the Department of Commerce may pilot the airplane during such parts of the tests as may be deemed necessary.

(5) No persons other than the crew necessary to conduct the flight shall be carried during performance tests. Sand or similar ballast shall be carried as a substitute for the passengers or cargo ordinarily carried as pay load.

(*I*) EQUIPMENT AND INSTRUMENT REQUIREMENTS. — The equipment and instruments required, which must be serviceable and in operating condition, are:

(1) *Equipment.*—(*a*) Fire-extinguishing equipment, of design

approved by the Secretary of Commerce. Cabin airplanes carrying passengers for hire must be equipped with at least one portable extinguisher accessible to the passengers.

(*b*) First-aid kits on airplanes carrying passengers for hire.

(*c*) Safety belts or equivalent apparatus for pilots and passengers in open-cockpit airplanes carrying passengers for hire. Seats or chairs in cabin planes shall be firmly secured in place.

(*d*) Electrical equipment and installation must be approved by the Secretary of Commerce.

(2) *Instruments.*—(*a*) Tachometer for each engine.

(*b*) Oil-pressure gauge where oil-pressure systems are employed.

(*c*) Water thermometer for water-cooled engines and oil thermometer for air-cooled engines.

(*d*) Altimeter.

(3) *Compass requirements.*—An airplane flying cross country 100 or more miles and an airplane, including a seaplane, operating over large bodies of water beyond the sight of land must be equipped with a compass.

(*J*) MANUFACTURER'S IDENTIFICATION DATA.—(1) The date of manufacture or date of remodeling and the name of the manufacturer or remodeler, together with the manufacturer's serial number and type of engine, must be permanently affixed in a visible location by means of a metal plate in the pilot's cockpit or compartment, of each airplane, in order that it may be distinguished from all other aircraft.

(2) The following specifications shall be stenciled or otherwise displayed on the outside of the fuselage or cabin at a point adjacent to the entrance into the cockpit or cabin in such manner as to be readily visible to persons proposing to enter the same: Over-all span; over-all length; weight empty; useful load; gross

weight; seating capacity, exclusive of crew; gasoline capacity; oil capacity.

(3) Upon airplanes manufactured under an approved type certificate the manufacturer thereof may display the insignia shown herewith, in conjunction with the above data required to be stenciled on the airplane.

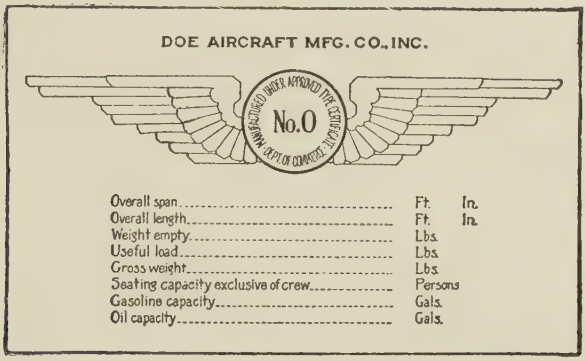

DOE AIRCRAFT MFG. CO., INC.
MANUFACTURED UNDER APPROVED TYPE CERTIFICATE DEPT. OF COMMERCE
No.0
Overall span ..... Ft. In.
Overall length ..... Ft. In.
Weight empty ..... Lbs.
Useful load ..... Lbs.
Gross weight ..... Lbs.
Seating capacity exclusive of crew ..... Persons
Gasoline capacity ..... Gals.
Oil capacity ..... Gals.

FIG. 2

The insignia, if used, shall be 16 inches in width and 3 inches in height and shall be identical with that shown except that the name of the manufacturer shall appear above it in the manner indicated, and the number of the approved type certificate under which the identical airplane was manufactured shall appear in the circle thereof. The stenciled data shall appear under it in the manner and proportion shown. This insignia shall only be used on airplanes for which application for license has been made, or for which license has been issued, and must be obliterated in the event the airplane is subsequently disapproved for license.

Sec. 11. Approved Type Certificate, Requirements for.

(*A*) APPLICATION.—A manufacturer of airplanes, engines, or propellers in quantities and of an exact similarity of type, structure, materials, assembly, and workmanship may, at the option

of the manufacturer, file with the Secretary of Commerce an application under oath for an approved type certificate accompanied by the data specified, in duplicate. The design or test data must bear the signature of the responsible engineer.

(*B*) AIRPLANES.—In order to represent the structure of an airplane satisfactorily the data submitted shall include—

(1) A general assembly drawing of each wing, with the sizes and locations of spars, drag struts, drag wires, leading edge, trailing edge, and members supporting the ailerons and controls clearly indicated.

(2) Drawings of a typical rib, showing method of attachment to the spars and leading edge.

(3) Line diagrams of the external wing bracing, showing truss dimensions, sizes of struts, and wires.

(4) Layout of the fuselage structure, showing sizes of all members of the primary structure.

(5) Drawings of the tail surfaces, showing sizes of spars, torque tubes, internal and external braces, location of hinges, and masts.

(6) Chassis drawings giving a layout of the landing gear that shows sizes of struts, axle, bracing wires, shock-absorber spindles, spreader tubes, and other important members and the method of connecting them. Drawings of the tail skid, showing the skid, its connection to the main fuselage structure, and the method of steering it, if any.

(7) For seaplanes, drawings of the floats, showing their lines, general dimensions, and a layout showing sizes of struts and wires and method of attachment to the fuselage.

(8) Detail drawings of the mechanisms used to adjust the stabilizer, fin, wing flaps, or similar surfaces while in flight.

(9) Drawings showing the main wing fittings and the control system are required. The analyses must cover the investigation

of the strength of the main members of the wings, tail surfaces, landing gear, including tail skids, fuselage, fittings, and control systems for the load factors required in section 10. The analysis of secondary members carrying heavy loads and the investigation of main members subjected to eccentric loads are required.

(10) Stress analysis of the control surfaces and control systems may be supplanted by tests made on these units, assembled as in flight, if the tests show that the unit will carry 125 per cent of the design load, and if the stick, rudder bar, etc., withstand the loads specified in section 10 (*C*).

(11) The stress analysis shall state the material used for members, whether or not it is heat-treated, and what physical properties are guaranteed, not assumed, by the manufacturer. If metal members of special design are used, test data showing their strength properties under loads similar to those to which they will be subjected in the structure must be submitted.

(*C*) ENGINES.—Data on engines, showing that the requirements of section 10 (*E*) and (*F*) have been complied with, and a complete set of drawings, must be submitted in duplicate by the engine manufacturer when applying for an approved type certificate.

(*D*) PROPELLERS.—Data on propellers, specified in section 10 (*G*), and a complete set of drawings must be submitted in duplicate by the propeller manufacturer when applying for an approved type certificate.

(*E*) INSPECTION AND FLIGHT TESTS OF AIRPLANES.—If the submitted design is approved and the aircraft meets the requirements stated herein, it will be inspected for exact similarity with the submitted design and specifications. Upon passing such inspection, the airplane must undergo the flight tests prescribed in section 10 (*H*). If such tests are passed, an approved type certificate will be issued to the manufacturer.

(*F*) CONSTRUCTION UNDER APPROVED TYPE CERTIFICATE.—The approved type certificate will be issued upon the condition that each quarter the manufacturer will file his affidavit with the Secretary of Commerce, showing the number of airplanes, engines, or propellers constructed under the approved type certificate during the quarter, with a statement that no airplane, engine, or propeller is being constructed, under such certificate, deviating from the terms thereof.

(*G*) CHANGES.—Changes in airplanes constructed under an approved type certificate are permissible, with the approval of the Secretary of Commerce.

(*H*) MANUFACTURER'S AFFIDAVIT.—Upon the sale by the manufacturer of airplanes of an exact similarity of type, structure, materials, assembly, and workmanship with the specimen for which the approved type certificate is issued, the manufacturer may deliver to the purchaser a manufacturer's affidavit, copies of which will be furnished the manufacturer upon request.

Sec. 12. Application for Aircraft License.

Before an aircraft license will be issued, the owner must file, under oath, with the Secretary of Commerce, an application for the license upon blanks provided by the Secretary of Commerce. Copies thereof will be forwarded upon request.

Sec. 13. Licensing and Expediting the Licensing of Approved Type Airplanes.

(*A*) For the purpose of expediting the licensing of airplanes constructed under approved type certificates and in the original possession of the manufacturer or dealer, the following provisions may be invoked, at the option of the manufacturer or dealer. The manufacturer or dealer may present the manufacturer's affidavit showing that the aircraft is exactly similar to the specimen of the approved type and have the airplane flight tested. If the flight

tests prescribed in section 10 are passed and the aircraft inspector finds that the airplane is exactly similar to the specimen, a flight certificate will be issued for such airplane, good for 90 days after date and renewable for 90-day periods upon findings of the Secretary of Commerce that the airplane is in substantially the same condition as when the original certificate was issued. The manufacturer's affidavit and the flight certificate may be delivered to any purchaser and will be given such effect as is provided therefor in paragraph (*B*) of this section.

(*B*) An airplane constructed under an approved type certificate and in the possession of and owned by an eligible owner of aircraft of the United States will be licensed as follows:

(1) If the application is accompanied by the manufacturer's affidavit, the airplane will be inspected for similarity to the specimen and will be given the flight tests prescribed in section 10. If such inspections and tests are passed and the airplane is found to be equipped as required by these regulations, it will be licensed.

(2) If the application is accompanied by both the manufacturer's affidavit and a valid flight certificate, it will be licensed if found to be equipped as required by these regulations.

(3) If the application is not accompanied by the manufacturer's affidavit and the flight certificate, it will be licensed under the provision of section 14 hereof.

Sec. 14. Licensing of Airplanes not Constructed under Approved Type Certificates.

(*A*) For an airplane constructed after October 1, 1927, and not manufactured under approved type certificate, the application for the license must be accompanied by the information specified in the requirements for approved type certificate.

(*B*) *Tests.*—(1) For an airplane constructed after October 1, 1927, in conformity to the airworthiness requirements of these

regulations and which passes the flight tests specified in section 10, an aircraft license will be issued by the Secretary of Commerce.

(2) For airplanes constructed prior to October 1, 1927, and found by the Secretary of Commerce to be of proper design, assembly, and workmanship, and of suitable materials and equipped in accordance with these regulations, aircraft licenses will be issued after such airplanes have passed the flight tests specified in section 10.

Sec. 15. Licensing of Special Classes of Airplanes.

Racing and experimental airplanes and airplanes of unusual design will be granted special aircraft licenses, and other aircraft may be specially licensed for other purposes and shall be operated only in accordance with the conditions specified in such licenses.

Sec. 16. Places for Airworthiness Tests.

The Secretary of Commerce will fix the time and place for all inspections and tests for airworthiness.

Sec. 17. Licenses—Contents.

Aircraft licenses will be issued for a period of not exceeding one year and will identify the airplane, specify the authorized type of the engine and the authorized gross weight, and will be granted subject to compliance with these regulations.

Sec. 18. Sale of Licensed Aircraft.

On the date of sale or transfer of title of licensed aircraft the vendor shall report in writing to the Secretary of Commerce the date and place of sale or transfer, and the name and residence of the vendee, and on said date return to the Secretary of Commerce the aircraft license and the metal plate furnished by the Secretary of Commerce.

If the sale is to an ineligible owner of aircraft of the United States, the aircraft license terminates as of the date of such sale. If the vendee is an eligible owner, he is responsible for filing with the Secretary of Commerce a properly executed purchaser's renewable application, if such vendee desires to have the aircraft licensed in his name for the unexpired term of said license. In the event the vendee does not elect to have the aircraft relicensed or is not an eligible owner, application, in duplicate, for identification mark shall be made to the Secretary of Commerce. In such case the vendee shall cause to be removed or obliterated from the aircraft the letter or letters which precede the license numeral or numerals.

The vendee, if an eligible owner of licensed aircraft, may, under the license number already assigned, operate the aircraft for a period of 20 days from the date of mailing the application or delivering the same in person to the Secretary of Commerce. In no case shall this period extend beyond 30 days from the date of sale. In all cases the vendee must attach to his application the bill of sale or a certified copy thereof.

Between the date of sale and the posting in the mails or delivery in person to an authorized representative of the Secretary of Commerce of the purchaser's renewable application or application for identification mark the aircraft is considered unlicensed and unidentified, and the operation thereof constitutes a violation of these regulations.

Sec. 19. Relicensing of Aircraft.

Upon the expiration of the term of an existing aircraft license the aircraft will be relicensed for additional periods of not exceeding one year upon the application of the licensed owner for relicensing and the finding of the Secretary of Commerce that the aircraft is airworthy and is owned by an eligible owner.

Sec. 20. Display and Surrender of License.

The aircraft license must be carried in the aircraft whenever it is in service and must be conspicuously posted where it may be readily seen by passengers or inspectors. Whenever the craft is unairworthy the license must be removed from the craft, and when the license is suspended or revoked, or when it is no longer in force, it shall be surrendered to the Secretary of Commerce. The license must be presented for inspection upon the demand of any passenger or of any authorized official or employee of the Department of Commerce or State or municipal officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 21. Licensing of Airships and Balloons.

Until otherwise provided by regulations, the licensing of airships and balloons shall be in accordance with special orders of the Secretary of Commerce.

Sec. 22. Meaning of Airplane.

Except as otherwise specifically shown, the word "airplane" as used in this chapter includes seaplane, or any combination of landplane, seaplane, or boat.

Sec. 23. Canceling Licenses upon Request.

Upon the request of the licensed owner the aircraft license will be canceled by the Secretary of Commerce.

Sec. 24. Revocation and Suspension of Licenses—Law.

*"The Secretary of Commerce shall by regulation * * * provide for the * * * suspension and revocation of registration (and) aircraft certificates."* (*Sec. 3 (f).*)

Sec. 25. Ground for Revocation or Suspension.

Aircraft licenses will be suspended or revoked for—

(*A*) Violating the air commerce act or any of these regulations.

(*B*) Failing to make proper and seasonable reports.

(*C*) Making false statement in application or information accompanying the application for the license, or in any report required under these regulations.

(*D*) Equipping the airplane with a type of engine not specified in the license or approved by the Secretary of Commerce.

(*E*) Remodeling the engine and using it to propel licensed aircraft without the aircraft having been first rerated as airworthy by the Secretary of Commerce.

(*F*) Remodeling the airplane structure and flying the airplane without having it first rerated as airworthy by the Secretary of Commerce.

(*G*) Operating the airplane in excess of the authorized useful load specified in the license.

(*H*) Operating with passengers in excess of the original designed seating arrangement. Infants under 2 years of age are excepted, provided the maximum allowable useful load is not exceeded.

(*I*) Using or displaying license for fraudulent purposes.

(*J*) Using or displaying license in any manner contrary to the public safety or interest.

Inspection of Aircraft

Sec. 26. Continuous Duty as to Flying Condition.

After an aircraft is licensed, and between the times that it is inspected for airworthiness by an inspector, the owner is charged with the continuous duty of maintaining the aircraft in a good and proper state of repair and flying condition. For violation of this duty or of the inspections required in the next succeeding section the aircraft license will be suspended or revoked.

Sec. 27. Daily and Periodic Inspections.

(*A*) A licensed airplane shall be given a line inspection by the owner or a licensed mechanic at least once within each 24 hours preceding flight, and the result thereof shall be entered in the log under the signature of the person making such inspection. The line inspection must be made to ascertain the working condition and state of repair of the—

(1) Open control wires, all control wires and pulleys open to inspection through apertures, and all hinges on control surfaces.

(2) Landing gear, wheels, fittings, and shock absorbers.

(3) Fuselage parts open to visual inspection.

(4) Main plane external bracing, including fittings and struts, external wires, cables, turnbuckles, and fabric or covering.

(5) Control surface fabric or covering.

(6) Engine-exhaust manifolds and exhaust-pipe extensions. The engine shall be given a warming-up test, during which the proper functioning of the engine instruments shall be ascertained.

(7) Carburetors and fuel-feed lines open to visual inspection to insure proper functioning.

(8) Cooling system and connections.

(9) Cowling, to insure that the cowlings are properly secured and safetied.

(10) Propellers, as to condition.

(*B*) After each 100 hours of flight, in addition to the line inspection, the airplane must be given a "periodic inspection" by the owner, and the result thereof must be entered in the log by the person making such inspection. This inspection must be made to ascertain the working condition and state of repair of the—

(1) Engine installation.

(2) Control systems throughout.

(3) Propeller alignment.

(4) Fuselage, including fittings, tail skid, and tail-skid shock absorbers.

Sec. 28. Government Inspections.

The inspector or other authorized officer of the Secretary of Commerce shall be permitted by the owner or operator to inspect the licensed aircraft at any time and place for the purpose of determining its flying condition and state of repair. For such purposes the owner or operator shall give to such inspector of officer free and uninterrupted access to the aircraft and the field or shelter where the craft is located.

Operation of Aircraft

Sec. 29. Solo Flights with Passenger Planes.

In addition to the requirements of section 10 (*E*), licensed airplanes with newly installed engines, old, new, or reconditioned, and airplanes upon which major repairs have been made to the plane structure, must be first test flown by a licensed pilot without passenger for hire.

Sec. 30. Carrying Passengers at Night.

Licensed aircraft, when engaged in carrying passengers for hire any time between one-half hour after sunset and one-half hour before sunrise, must be equipped with electric landing lights and navigation lights.

Sec. 31. Supplies and Equipment for Flights over Water.

An airplane flying over large bodies of water must be provided with an adequate supply of food and potable water, and, if engaged in carrying passengers for hire, it must be equipped with a Very's pistol or approved equivalent and life preservers or other flotation devices approved by the Secretary of Commerce.

Sec. 32. Repairs after Accident Reports.

After repairs have been made on a licensed aircraft which has been seriously damaged, the licensed owner shall make full report to the Secretary of Commerce of the kind and extent of repairs made to the craft.

Sec. 33. Flying Seriously Damaged Airplanes.

A licensed airplane which is seriously damaged must not be flown with passengers for hire until it has been fully repaired and its flying condition approved by an inspector.

Sec. 34. Accident Reports.

Where serious injury to person or property is suffered or death results in operating licensed aircraft, the owner of such aircraft shall immediately report, by telegraph or telephone, to the Secretary of Commerce, the license number or identification number of the aircraft and the time and place of the accident. All accidents in the operation of licensed aircraft which result in injury to the aircraft shall be reported without delay on the form provided for that purpose.

Sec. 35. Logs and Navigation Reports.

The owner or operator of every licensed aircraft shall keep a navigation and engine log book and shall quarterly transmit to the Secretary of Commerce a navigation summary report, in duplicate, showing the number of hours and the approximate number of miles the aircraft has been flown during the quarter, the duration of the use of each engine, the engine installation and repairs, and the plane structure and rigging changes and repairs.

The log books shall be carried in the aircraft at all times when such aircraft is away from its home airport.

Sec. 36. Foreign Air Commerce.

Until otherwise provided, the laws of the United States and regulations made thereunder with respect to the entry and clear-

ance of vessels engaged in foreign commerce are hereby made applicable to aircraft engaged in foreign air commerce.

Making of Licensed and Unlicensed Aircraft

Sec. 37. Marking of Aircraft, Law of.

*"The Secretary of Commerce shall by regulation * * * establish air traffic rules for the * * * identification of aircraft * * *."* (*Sec. 3 (e).*)

Sec. 38. Identification Marks for Government and Special Classes of Aircraft.

(*A*) For aircraft belonging to the Government of the United States identification marks or symbols will be assigned in accordance with arrangements to be made with the affected departments.

(*B*) Licensed airplanes engaged in racing or experimental work, or specially licensed for other purposes, will be assigned special identification numbers or symbols.

Sec. 39. Identification Marks for Licensed Aircraft.

A licensed aircraft shall bear an identification mark consisting of the license number of the aircraft preceded by—

The Roman capital letter S (meaning State) for aircraft used solely for governmental purposes and belonging to States, Territories, possessions or political subdivisions thereof, and

The Roman capital letter C for all other licensed aircraft.

Aircraft not licensed, but eligible and for which application for license has been filed with the Secretary of Commerce, will be assigned only a temporary number pending the issuance of license.

The letter N must precede the license symbol and numerals on licensed aircraft engaged in foreign air commerce and, at the option of the owner, may precede it on other licensed aircraft. *The identification mark will be assigned to licensed aircraft when the*

aircraft license is issued, and a separate application is not required.

Sec. 40. Identification Marks for Unlicensed Aircraft.

(*A*) Unlicensed aircraft must display, when in flight, an identification mark assigned by the Secretary of Commerce. The mark will be assigned upon the application of the aircraft owner and must be permanently affixed to the aircraft. It will consist of a number only. The nationality mark shall not be made a part of it, nor shall any other letter, design, symbol, or description be added thereto.

(*B*) On the date of sale or transfer of title of unlicensed identified aircraft the vendor shall report in writing to the Secretary of Commerce, advising the date and place of sale or transfer, and the name and residence of the vendee, and on said date shall return to the Secretary of Commerce the metal plate furnished by the Secretary of Commerce and the identification-mark assignment issued for such aircraft.

(*C*) Upon such sale the identification mark may be reassigned to the vendee, provided he files an original application for identification mark, in duplicate, with the Secretary of Commerce, requesting such reassignment and attaches to the application the bill of sale or a certified copy thereof.

(*D*) The vendee may operate such aircraft under the identification mark already assigned for a period of 20 days from the date of filing the application. In no event shall such period extend beyond 30 days from the date of sale.

(*E*) Between the date of sale and date of posting in the mails or delivery in person to an authorized representative of the Secretary of Commerce of the new application the aircraft is considered unidentified, and its operation will constitute a violation of these regulations.

Sec. 41. Places and Dimensions of Marks.

Identification marks shall be located as follows:

(*A*) On airplanes.—On the lower surface of the lower left wing and the upper surface of the upper right wing, the top of the letters or figures to be toward the leading edge, the height to be at least four-fifths of the mean chord; provided, however, that in the event four-fifths of the mean chord is more than 30 inches, the height of the letters and figures need not be more but shall not be less than 30 inches. If the lower left plane is less than one-half the span of the upper left plane, the letters or figures thus described shall be on the under surface of the upper left plane, as far to the left as is possible. In the case of a monoplane the mark shall be displayed on the lower surface of the left wing and the upper surface of the right wing in the manner thus described. The marks shall also appear on both sides of the rudder, of size as large as the surface will permit, leaving a margin of at least 2 inches.

(*B*) On airships.—On both sides near the maximum cross section and on the lower under surface of the nose, the height to be equal to at least one-twelfth of the circumference at the maximum transverse cross section of the airship, but it need not exceed 8 feet.

(*C*) On balloons.—Twice, near the maximum horizontal circumference, as far as possible from one another, the height to be equal to at least one-twelfth of the circumference of the balloon, but it need not exceed 8 feet.

(*D*) The width of the letters and figures of all marks shall be at least two-thirds of the height, and the width of the stroke shall be at least one-sixth of the height. The letters and figures shall be painted in plain black type on a white background or in any color on any background, but there must be a strong contrast between the two. The letters and numbers must be uniform in

shape and size. A space equal to at least one-half of the width of a letter shall be left between each figure or letter.

Sec. 42. Other Symbols and Marks.

Except with the approval of the Secretary of Commerce, no design, mark, character, symbol, or description shall be placed upon aircraft if said design, etc., modifies, adds to, or subtracts from, or confuses the assigned mark or impairs or destroys its visibility.

Sec. 43. License and Identification Plates.

The license number or identification mark, with the name and residence of the owner, will be inscribed upon a metal plate furnished by the Secretary of Commerce. It must be affixed to the fuselage in a prominent place, but this section shall not apply to public aircraft of the United States used exclusively in the governmental service.

The plate will distinguish on its face between licensed and unlicensed aircraft.

Licensing of Pilots

Sec. 44. Pilots, Law of.

*"The Secretary of Commerce shall by regulation * * * provide for the periodic examination and rating of airmen serving in connection with aircraft of the United States as to their qualifications for such service."* (*Sec. 3 (c).*)

"The term 'airman' means any individual (including the person in command and any pilot, mechanic, or member of the crew) who engages in the navigation of aircraft while under way, and any individual who is in charge of the inspection, overhauling, or repairing of aircraft." (*Sec. 9 (k).*)

*"It shall be unlawful * * * to serve as an airman in connec-*

*tion with any aircraft registered as an aircraft of the United States * * * without an airman certificate or in violation of the terms of any such certificate." (Sec. (11) (a) (4).)*

*. "Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of $500." (Sec. (11) (b).)*

Sec. 45. Application of the Law.

For the purpose of this chapter, persons in command of or piloting licensed aircraft in flight will be classed as pilots.

Sec. 46. Classification of Pilots.

Licensed pilots are classed as commercial or private pilots. Commercial pilots are licensed as transport, limited commercial, or industrial pilots. Private pilots are designated as private pilots (without other qualifications) or as student pilots. A person may hold a plurality of licenses, such as a pilot's and mechanic's license. A transport pilot will not be issued other classes of pilots' licenses.

Sec. 47. Privileges and Restriction of Licensed Pilots.

Except as otherwise provided in these regulations, the privileges conferred and restrictions imposed upon licensed pilots are as follows:

(*A*) Transport pilots may pilot any type of licensed aircraft but not unlicensed aircraft carrying persons or property for hire. Transport pilots shall have all of the privileges of navigating aircraft conferred upon other classes of pilots, which shall include the right to instruct students in the operation of aircraft in flight.

(*B*) Limited commercial pilots shall have all of the privileges conferred and be subject to all of the restrictions imposed upon transport pilots, except they shall not pilot aircraft carrying per-

sons for hire outside of the areas mentioned in their licenses, nor shall they, for hire, instruct students in the operation of aircraft in flight.

(*C*) Industrial pilots may pilot any type of licensed aircraft not carrying persons for hire but shall not pilot unlicensed aircraft carrying either persons or property for hire and shall not, for hire, instruct students in the operation of aircraft in flight.

(*D*) Private pilots, not designated as students, may pilot licensed aircraft but shall not carry persons or property for hire in licensed or unlicensed aircraft. Private pilots designated as students are licensed only for the purpose of piloting licensed aircraft when receiving flying instructions and such student pilots shall not pilot licensed aircraft carrying persons or property for hire or for any other purpose than receiving flying instructions nor within any other area than that specified in their licenses. Private pilots shall not, for hire, instruct students in the operation of aircraft in flight.

Sec. 48. Applications for Pilots' Licenses.

An application for a pilot's license must be filed, under oath, with the Secretary of Commerce upon blanks furnished for that purpose. An applicant for a pilot's license, including a student's pilot license, must appear for a physical examination before a physician designated by the Secretary of Commerce and pass such examination, unless he is exempt under these regulations.

Sec. 49. Character, Age, and Citizenship Qualifications.

An applicant for a pilot's license must be of good moral character. The minimum age requirements are 16 years for private pilots and 18 years for industrial, limited commercial, and transport pilots. A private pilot may be a citizen of any country. An industrial, limited commercial, or transport pilot must be (1) a citizen of the United States, or (2) a citizen of a foreign country

which grants reciprocal commercial-pilot privileges to citizens of the United States on equal terms and conditions with citizens of such foreign country, or (3) an alien who has filed his declaration of intention to become a citizen of the United States and advises the Secretary of Commerce of the serial number of such declaration, the date thereof, and the court in which filed. He must diligently and successfully prosecute the naturalization proceedings under penalty of the revocation of his pilot's license and from time to time must keep the Secretary of Commerce advised of the status of such proceedings.

Sec. 50. Flying Experience Requirements.

An applicant must have at least the following flying experience:

(*A*) TRANSPORT PILOTS.—Two hundred hours of solo flying, of which at least five hours must have been within the last preceding 60 days prior to the filing of the application.

(*B*) LIMITED COMMERCIAL PILOTS.—The same solo flying required of industrial pilots.

(*C*) INDUSTRIAL PILOTS.—Fifty hours of solo flying, of which at least 5 hours must have been within the last preceding 60 days prior to the filing of the application.

(*D*) PRIVATE PILOTS.—Private pilots not designated as students, 10 hours solo flying, of which at least 2 hours must have been within the last preceding 60 days prior to the filing of the application.

Sec. 51. Pilot's Physical Qualification.

The physical examinations provided for herein must be accomplished before the practical and theoretical tests will be given. The qualifications are as follows:

(*A*) PRIVATE PILOTS.—Absence of organic disease or defect which would interfere with safe handling of an airplane under the conditions of private flying; visual acuity of at least 20/40

in each eye; less than 20/40 may be accepted if the pilot wears a correction in his goggles bringing his vision approximately to normal and has normal judgment of distance without correction (however, in the case of student pilots this will not apply, but if a student has 20/50 in one eye and 20/40 or better in the other, with normal judgment of distance, without correction, he may be accepted if his physical condition is satisfactory, and if his vision can be corrected approximately to normal by goggles); good judgment of distance; no diplopia in any position; normal visual fields and color vision; no organic disease of eye or internal ear.

(*B*) Industrial pilots.—Absence of any organic disease or defect which would interfere with the safe handling of an airplane; visual acuity of not less than 20/30 in each eye, although in certain instances less than 20/30 may be accepted if the applicant wears a correction to 20/20 in his goggles and has good judgment of distance without correction; good judgment of distance; no diplopia in any field; normal visual fields and color vision; absence of organic disease of the eye, ear, nose, or throat.

(*C*) Limited commercial pilots.—The same physical qualifications prescribed for transport pilots.

(*D*) Transport pilots.—Good past history; sound pulmonary, cardiovascular gastrointestinal, central nervous, and genito-urinary systems; freedom from material structural defects or limitations; freedom from disease of the ductless glands; normal central, peripheral, and color vision; normal judgment of distance; only slight defects of ocular muscle balance; freedom from ocular disease; absence of obstructive or diseased conditions of the ear, nose, and throat; no abnormalities of equilibrium that would interfere with flying.

(*E*) Waivers.—In the case of trained, experienced flyers the Secretary of Commerce may grant waivers for physical defects designated as disqualifying by these regulations when in his opin-

ion the experience of the pilot will compensate for the defect. A waiver once granted will hold indefinitely so long as the defect for which it was granted has not increased or unless canceled by the Secretary of Commerce.

Sec. 52. Exemption from Prescribed Physical Examination.

An applicant for a pilot's license (or its renewal) will be exempt from the physical examination prescribed in these regulations upon filing with the Secretary of Commerce a certified copy of the examination for flying in the United States Army, Navy, or Marine Corps made within six months of the date of filing his application for his pilot's license or its renewal, provided his physical qualifications as shown by such copy of the examination are not less than those required by these regulations for the class of license for which he applies.

Sec. 53. Pilots' Examinations and Tests.

Unless exempt under these regulations, candidates must pass the following examinations and tests:

(*A*) TRANSPORT PILOTS.—(1) Examination on the air traffic rules and those portions of the Air Commerce Regulations pertaining to pilots' privileges and limitations and to the inspection and operation of aircraft.

(2) Practical and theoretical examination in elementary engine and plane mechanics and rigging and a theoretical examination in the fundamentals of meteorology and air navigation.

(3) Practical flight test, as follows:

(*a*) In addition to normal take-offs and landings, the following maneuvers will be required: from 1,500 feet, with engine throttled, make a 360° turn and land in normal landing attitude, by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(*b*) From 1,000 feet, with engine throttled, make a 180° turn

and land in normal landing attitude, by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(*c*) A series of five gentle and three steep figure 8 turns from 800 to 1,000 feet, respectively. Spiral in one direction from 2,000 feet, with engine throttled, and land in normal landing attitude by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(*d*) Fly in emergency maneuvers, doing spirals, side slips, climbing turns, and recovering from stalls.

(*e*) Fly over a triangular or rectangular course at least 100 miles, landing at place of take-off within at least five hours. This flight shall also include two obligatory landings, not at point of departure, when craft must come to rest. The course will be designated and the candidate will be furnished with route information by the examiner for the Department of Commerce at time of departure, and the examiner for the Department of Commerce will determine whether the course was correctly followed and whether obligatory landings were satisfactory. Upon the presentation of satisfactory proof that the candidate has engaged in solo-cross-country flights a distance of at least 100 miles within one year preceding the date of his application, the flight specified in this subsection will be omitted.

(*f*) Cross-wind landings and take-offs.

(*B*) LIMITED COMMERCIAL PILOTS.—The same examinations and tests as are prescribed for transport pilots, except the cross-country flight and the examination on elementary meteorology and navigation.

(*C*) INDUSTRIAL PILOTS.—(1) Examination on the air traffic rules and practical and theoretical examination in elementary engine and plane mechanics and rigging and those portions of the Air Commerce Regulations pertaining to pilots' privileges and

limitations and to the inspection and operation of aircraft.

(2) The practical flight tests prescribed for transport pilots, except the distance for the cross-country flight shall be 60 miles.

(*D*) PRIVATE PILOTS.—(1) Examination on the air traffic rules and those portions of the Air Commerce Regulations pertaining to pilots' privileges and limitations and to the inspection and operation of aircraft.

(2) The practical flight test specified in subparagraph 3 (*c*) of section 53 (*A*) and three satisfactory landings to a full stop. A private pilot, classed as a student, will be licensed without being required to pass the examination and tests prescribed in this subparagraph.

(*E*) REËXAMINATION.—Applicants for pilots' licenses who have failed to successfully accomplish the prescribed theoretical or practical tests may apply for reëxamination at any time after the expiration of 90 days from the date of such failure.

If the physical examination has expired for the class of license for which application has been made, a new physical examination must be submitted.

The minimum passing grade for any subject in the foregoing theoretical examinations shall be 70 per cent.

Practical tests must be accomplished to the satisfaction of the examiner for the Department of Commerce.

Sec. 54. Place, etc., of Examinations.

Examinations for pilots' licenses will be held at such times and places as the Secretary of Commerce shall designate. Such examinations and tests will be conducted by an examining officer designated by the Secretary of Commerce. Candidates for pilots' licenses must furnish the airplanes in which the flight tests are to be made, unless the Secretary of Commerce makes other provisions therefor.

Sec. 55. Duration and Renewal of Pilots' Licenses.

(*A*) Unless sooner revoked, transport and limited commercial pilots' licenses shall remain in force for six months and industrial and private pilots' licenses one year from date of issuance. Before any license is renewed, the Secretary of Commerce may, in his discretion, require the holder of such license to undergo any of the theoretical or practical tests prescribed as requisites for the original license.

(*B*) Licenses will be renewed for like periods where the prescribed physical condition of the holder is shown by the same method as when the original license was issued, except that a transport or limited commercial pilot must prove that he has had at least 10 hours of solo flying within the last 60 days, industrial pilots at least 25 hours within the last year, and private pilots at least 10 hours within the last year.

(*C*) If an applicant for renewal has not had the required solo flying and applies for a renewal within six months after the expiration of his last license, a new license will be issued to him upon proof of his physical qualifications and the passing of the flight tests required for the class of license he last held.

(*D*) Upon application to and permission of the Secretary of Commerce the area for permissible flying of aircraft carrying passengers, for hire, designated in the license of limited commercial pilots, will be changed to other areas.

(*E*) Upon application and for good cause shown the licenses specified in this chapter may be extended for 60 days.

Sec. 56. Personal Possession of Pilots' Licenses.

The pilot's license shall be kept in his personal possession when he is piloting aircraft and must be presented for inspection upon the demand of any passenger or any authorized official or employee of the Department of Commerce or State or municipal

officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 57. Pilots' Flight Records.

A licensed pilot must keep an accurate record of his flying time in a log book. It is the pilot's responsibility to obtain and maintain this log book.

Sec. 58. Carrying Passengers in Various Classes of Airplanes.

A licensed pilot, authorized to transport passengers, for hire; shall not do so in a type of aircraft which he has not previously operated within the last preceding 90 days for at least two hours, including 10 landings, 3 of which must have been to a full stop.

Sec. 59. Seaplane Piloting.

A licensed pilot shall not carry passengers, for hire, in a seaplane unless he has polited a seaplane for at least two hours within the last preceding 90 days, except where he makes practice flights in the seaplane for at least one-half hour and takes it off and lands it at least ten times. At least three of the landings must be to a full stop.

Sec. 60. Pilots' Night-Flying Qualifications.

A transport or limited commercial pilot who has not had at least two hours of night solo flying within the last preceding 90 days shall not pilot aircraft carrying passengers, for hire, between one-half hour after sunset and one-half hour before sunrise, except where he takes off and lands between one-half hour after sunset and one-half hour before sunrise, at least ten times solo. At least three of such landings must be to a full stop.

Sec. 61. Meaning of Solo Flying.

As used in these regulations, a person is engaged in solo flying when he is the sole operator of the controls and is in command of aircraft, in flight.

Sec. 62. Suspension or Revocation of Licenses.

Pilots' licenses will be suspended or revoked for—

(*A*) Violating any provision of the air commerce act of 1926 or these regulations.

(*B*) Carelessness or inattention to duty.

(*C*) Unsound physical condition or any demonstration of incompetency in the operation or repair of aircraft.

(*D*) Being under the influence, or using, or having personal possession of intoxicating liquor, cocaine, or other habit-forming drugs while on duty.

(*E*) Refusal to exhibit license upon proper demand.

(*F*) Violating air traffic rules.

(*G*) Making any false statement in application for license or in any reports required to be submitted by these regulations.

(*H*) Carrying passengers who are obviously under the influence of intoxicating liquor, cocaine, or other habit-forming drugs.

(*I*) Piloting aircraft carrying passengers in excess of the original designed seating arrangements of the aircraft. Infants under 2 years of age are excepted, provided the maximum useful load is not exceeded.

(*J*) Doing any act in connection with aircraft which is contrary to the public safety or interest or detrimental to the morale of pilots or mechanics.

Licensing of Mechanics

Sec. 63. Mechanics, Law of.

*"The Secretary of Commerce shall by regulation * * * provide for the periodic examination and rating of airmen serving in connection with aircraft of the United States as to their qualifications for such service."* (*Sec. 3 (c).*)

"The term 'airman' means any individual (including the person in command and any pilot, mechanic, or member of the crew) who engages in the navigation of aircraft while under way, and any individual who is in charge of the inspection, overhauling, or repairing of aircraft." (*Sec. 9 (k).*)

*"It shall be unlawful * * * to serve as an airman in connection with any aircraft registered as an aircraft of the United States * * * without an airman certificate or in violation of the terms of any such certificate."* (*Sec. 11 (a) (4).*)

*"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of $500."* (*Sec. 11 (b).*)

Sec. 64. Application of the Law.

For the purpose of this chapter, persons repairing or adjusting licensed aircraft in flight and persons in charge of the ground inspection, overhauling, or repairing of licensed aircraft will be classed as mechanics. A workman or mechanic may engage in the repair or overhaul of licensed aircraft without being licensed if such repair or overhaul is in charge of a licensed mechanic. An application for a mechanic's license must be filed, under oath, with the Secretary of Commerce upon blanks furnished for that purpose. An applicant for a mechanic's license is not required to take a physical examination.

Sec. 65. Classification of Mechanics.

Mechanics are licensed as engine or airplane mechanics. A person may hold a plurality of licenses, such as both classes of mechanic's licenses or a pilot's and mechanic's license.

Sec. 66. Mechanics' Qualifications and Examinations.

(*A*) An applicant for an engine mechanic's license must have had at least two years' experience on internal-combustion engines,

one year of which must have been on aircraft engines. Such applicant will be licensed upon passing an examination on Air Commerce Regulations pertaining to the operation and inspection of aircraft and showing that he has sufficient knowledge of such engines and their accessories, including ignition systems, to properly inspect, maintain, repair, and overhaul the same.

(*B*) An applicant for an airplane mechanic's license must have had at least one year's actual experience in servicing aircraft. Such an applicant will be licensed upon passing an examination on Air Commerce Regulations pertaining to the operation and inspection of aircraft, showing he is sufficiently qualified in plane structure and rigging, including control systems, to properly inspect, maintain, repair, and overhaul the same.

(*C*) The examinations for both classes of license will be both theoretical and practical. The minimum passing grade in each subject covered shall be 70 per cent. A citizen of any country may be licensed if found qualified. Examinations for mechanics' licenses will be held at such times and places as the Secretary of Commerce shall designate. Such examinations and tests will be conducted by an examining officer designated by the Secretary of Commerce.

(*D*) Applicants for mechanic's licenses who have failed to successfully accomplish the prescribed theoretical or practical tests may apply for reëxamination at any time after the expiration of 90 days from the date of such failure.

Sec. 67. Duration and Renewal.

Mechanics' licenses, unless sooner suspended or revoked, will remain in force for two years after date of issue and will be renewed for additional two-year periods upon proof that during the term of the last license the holder has rendered services under his license during at least one-half of the term thereof. Upon

application and good cause shown the Secretary of Commerce may extend the license for a period of not more than 60 days. Before any license is renewed, the Secretary of Commerce may, in his discretion, require the holder of such license to undergo any of the theoretical or practical tests prescribed as requisites for the original license.

Sec. 68. Personal Possession of Mechanics' Licenses.

A mechanic's license shall be kept in his personal possession when he is serving in connection with licensed aircraft and must be presented for inspection upon the demand of any passenger in or owner of repaired licensed aircraft upon which such mechanic has worked, or any authorized official or employee of the Department of Commerce or State or municipal officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 69. Suspension or Revocation of Licenses.

Mechanics' licenses will be suspended or revoked for—

(*A*) Violating any provision of the air commerce act of 1926 or these regulations.

(*B*) Carelessness or inattention to duty.

(*C*) Any demonstration of incompetency in the repair or overhaul of aircraft.

(*D*) Being under the influence, or using, or having personal possession of intoxicating liquor, cocaine, or other habit-forming drugs while on duty.

(*E*) Refusal to exhibit license upon proper demand.

(*F*) Making any false statement in application for license or in any reports required to be submitted by these regulations.

(*G*) Doing any act in connection with aircraft which is contrary to the public safety or interest or detrimental to the morale of pilots or mechanics.

Air Traffic Rules

Sec. 70. Law.

"The Secretary of Commerce shall by regulation establish air traffic rules for the navigation, protection, and identification of aircraft, including rules as to safe altitudes of flight and rules for the prevention of collisions between vessels and aircraft." (*Air commerce act of 1926, sec. 3 (e).*)

Sec. 71. Unlawful Acts.

*"It shall be unlawful * * * to navigate any aircraft otherwise than in conformity with the air traffic rules."* (*Sec. 11 (a) (5).*)

Sec. 72. Penalty.

*"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of $500."* (*Sec. 11 (b).*)

Sec. 73. Application of the Law.

"In order to protect and prevent undue burdens upon interstate and foreign air commerce the air traffic rules are to apply whether the aircraft is engaged in commerce or noncommercial, or in foreign, interstate, or intrastate navigation in the United States, and whether or not the aircraft is registered or is navigating in a civil airway." (*Statement of managers accompanying conference report, air commerce act of 1926.*)

Sec. 74. Flying Rules.

(*A*) Right-side traffic.—Aircraft flying in established civil airways, when it is safe and practicable, shall keep to the right side of such airways.

(*B*) Giving-way order.—Craft shall give way to each other in the following order:

(1) Airplanes.

(2) Airships.

(3) Balloons, fixed or free.

An airship not under control is classed as a free balloon. Aircraft required to give way shall keep a safe distance, having regard to the circumstances of the case. Three hundred feet will be considered a minimum safe distance.

(*C*) GIVING-WAY DUTIES.—If the circumstances permit, the craft which is required to give way shall avoid crossing ahead of the other. The other craft may maintain its course and speed, but no engine-driven craft may pursue its course if it would come within 300 feet of another craft, 300 feet being the minimum distance within which aircraft, other than military aircraft of the United States engaged in military maneuvers and commercial aircraft engaged in local industrial operations, may come within proximity of each other in flight.

(*D*) CROSSING.—When two engine-driven aircraft are on crossing courses the aircraft which has the other on its right side shall keep out of the way.

(*E*) APPROACHING.—When two engine-driven aircraft are approaching head-on, or approximately so, and there is risk of collision, each shall alter its course to the right, so that each may pass on the left side of the other. This rule does not apply to cases where aircraft will, if each keeps on its respective course, pass more than 300 feet from each other.

(*F*) OVERTAKING.—(1) *Definition.*—An overtaking aircraft is one approaching another directly from behind or within 70° of that position, and no subsequent alteration of the bearing between the two shall make the overtaking aircraft a crossing aircraft within the meaning of these rules or relieve it of the duty of keeping clear of the overtaken craft until it is finally past and clear.

(2) *Presumption.*—In case of doubt as to whether it is forward or abaft such position it should assume that it is an overtaking aircraft and keep out of the way.

(3) *Altering course.*—The overtaking aircraft shall keep out of the way of the overtaken aircraft by altering its own course to the right, and not in the vertical plane.

(*G*) HEIGHT OVER CONGESTED AND OTHER AREAS.—Exclusive of taking off from or landing on an established landing field, airport, or on property designated for that purpose by the owner, and except as otherwise permitted by section 79, aircraft shall not be flown—

(1) Over the congested parts of cities, towns, or settlements, except at a height sufficient to permit of a reasonably safe emergency landing, which in no case shall be less than 1,000 feet.

(2) Elsewhere at height less than 500 feet, except where indispensable to an industrial flying operation.

(*H*) HEIGHT OVER ASSEMBLY OF PERSONS.—No flight under 1,000 feet in height shall be made over any open-air assembly of persons except with the consent of the Secretary of Commerce. Such consent will be granted only for limited operations.

(*I*) ACROBATIC FLYING.—(1) Acrobatic flying means intentional maneuvers not necessary to air navigation.

(2) No person shall acrobatically fly an aircraft—

(*a*) Over a congested area of any city, town, or settlement.

(*b*) Over any open-air assembly of persons or below 2,000 feet in height over any established civil airway, or at any height over any established airport or landing field, or within 1,000 feet horizontally thereof.

(*c*) Any acrobatic maneuvers performed over any other place shall be concluded at a height greater than 1,500 feet.

(*d*) No person shall acrobatically fly any airplane carrying passengers for hire.

(*e*) *Dropping objects or things.*—When an aircraft is in flight the pilot shall not drop or release, or permit any person to drop or release, any object or thing which may endanger life or injure property, except when necessary to the personal safety of the pilot, passengers, or crew.

(*J*) SEAPLANES ON WATER.—Seaplanes on the water shall maneuver according to the laws and regulations of the United States governing the navigation of water craft, except as otherwise provided herein.

(*K*) TRANSPORTING EXPLOSIVES.—The transporting of any explosives other than that necessary for signaling or fuel for such aircraft while in flight or materials for industrial and agricultural spraying (dusting) is prohibited, except upon special authority obtained from the Secretary of Commerce.

Sec. 75. Take-off and Landing Rules.

(*A*) METHOD.—Take-offs and landings shall be made upwind when practicable. The take-off shall not be commenced until there is no risk of collision with landing aircraft and until preceding aircraft are clear of the field. Aircraft when taking off or landing shall observe the traffic lanes indicated by the field rules or signals. No take-off or landing shall be made from or on a public street or highway without the consent of the local governing authority and the approval of the Secretary of Commerce.

(*B*) COURSE.—If practicable, when within 1,000 feet horizontally of the leeward side of the landing field the airplane shall maintain a direct course toward the landing zone.

(*C*) RIGHT OVER GROUND PLANES.—A landing plane has the right of way over planes moving on the ground or taking off.

(*D*) GIVING WAY.—When landing and maneuvering in preparation to land, the airplane at the greater height shall be responsible for avoiding the airplane at the lower height and shall,

as regards landing, observe the rules governing overtaking aircraft.

(*E*) Distress landings.—An aircraft in distress shall be given free way in attempting to land.

Sec. 76. Lights.

(*A*) Angular limits.—The angular limits laid down in these rules will be determined as when the aircraft is in normal flying position.

(*B*) Airplane lights.—Between one-half hour after sunset and one-half hour before sunrise airplanes in flight must show the following lights:

(1) On the right side a green light and on the left side a red light, each showing unbroken light between two vertical planes whose dihedral angle is 110° when measured to the left and right, respectively, from dead ahead. These lights shall be visible at least 2 miles.

(2) At the rear and as far aft as possible a white light shining rearward, visible in a dihedral angle of 140° bisected by a vertical plane through the line of flight and visible at least 3 miles.

(*C*) Airship lights.—Between one-half hour after sunset and one-half hour before sunrise airships shall carry and display the same lights that are prescribed for airplanes, excepting the side lights shall be doubled horizontally in a fore-and-aft position, and the rear light shall be doubled vertically. Lights in a pair shall be at least 7 feet apart.

(*D*) Balloon lights.—A free balloon, between one-half hour after sunset and one-half hour before sunrise, shall display one white light not less than 20 feet below the car, visible for at least 2 miles. A fixed balloon, or airship, shall carry three lights —red, white, and red—in a vertical line, one over the other, visible at least 2 miles. The top red light shall be not less than

20 feet below the car, and the lights shall be not less than 7 nor more than 10 feet apart.

(*E*) LIGHTS WHEN STATIONARY.—(1) Between one-half hour after sunset and one-half before sunrise all aircraft which are on the surface of water and not under control, or which are moored or anchored in navigation lanes, shall show a white light visible for at least 2 miles in all directions.

(2) Balloon and airship mooring cables between one-half hour after sunset and one-half hour before sunrise shall show groups of 3 red lights at intervals of at least every 100 feet, measured from the basket, the first light in the first group to be approximately 20 feet from the lower red balloon light. The object to which the balloon is moored on the ground shall have a similar group of lights to mark its position.

Sec. 77. Day Marks of Masts, etc.

By day, balloon and airship mooring cables shall be marked with tubular streamers not less than 8 inches in diameter and 7 feet long and marked with alternate bands of white and red, 20 inches in width. The object to which the balloon or airship is moored on the ground shall have the same kind of streamers, which must be in the same position as the lights specified herein.

Sec. 78. Signals.

(*A*) DISTRESS.—The following signals, separately or together, shall, where practicable, be used in case of distress:

(1) The international signal, S O S, by radio.

(2) The international-code flag signal of distress, NC.

(3) A square flag having either above or below it a ball, or anything resembling a ball.

(*B*) SIGNAL WHEN COMPELLED TO LAND.—When an aircraft is forced to land at night at a lighted airport it shall signal its forced

landing by making a series of short flashes with its navigation lights if practicable to do so.

(*C*) Fog signals.—In fog, mist, or heavy weather an aircraft on the water in navigation lanes, when its engines are not running, shall signal its presence by a sound device emitting a signal for about five seconds in two-minute intervals.

Sec. 79. Deviation from Air Traffic Rules.

The air traffic rules may be deviated from when special circumstances render a departure necessary to avoid immediate danger or when such departure is required because of stress of weather conditions or other unavoidable cause.

Miscellaneous

Sec. 80. Civil Penalties.

*Any person who (1) violates any provision of subdivision (a) of this section or any entry or clearance regulation made under section 7, or (2) any customs or public health regulation made under such section, or (3) any immigration regulation made under such section, shall be subject to a civil penalty of $500, which may be remitted or mitigated by the Secretary of Commerce, the Secretary of the Treasury, or the Secretary of Labor, respectively, in accordance with such proceedings as the Secretary shall by regulation prescribe * * * ." (Air commerce act of 1926, sec. 11 (b).)*

Sec. 81. Penalty Proceedings.

The Secretary of Commerce, or his duly authorized representative, will notify all persons of the incursion of penalties subject to mitigation or remission by the Secretary, and any person charged with a civil penalty may transmit to the Secretary of Commerce, within the time prescribed in the notification of such

penalty, an affidavit stating the facts upon which the request for mitigation or remission is based. The Secretary of Commerce will then determine whether or not the penalty will be mitigated or remitted, and the person making the request will be notified accordingly.

Sec. 82. Waiver of Regulations.

The Secretary of Commerce may waive any of the requirements of these regulations when, in his discretion, the particular facts justify such waiver.

Sec. 83 Savings Clause.

An aircraft required to be licensed under the air commerce act of 1926 may operate under a letter of authority from the Secretary of Commerce or his duly authorized representative pending the official inspection of such aircraft, provided an application for aircraft license is on file with the Secretary of Commerce and all the provisions of these regulations have been complied with.

In so far as these regulations amend the existing regulations they shall become effective on June 1, 1928, except as to sections 10 and 11, which shall become effective on August 1, 1928.

APPENDIX

EXAMINATION QUESTIONS FOR TRANSPORT PILOTS

Pilots expecting to take the examination for Transport Pilot should be prepared to work examples of the character given in the worked-out examples in this book, and also to answer questions of about the following nature:

Q1. Give a brief description of the magnetic compass used in aerial navigation.

Q2. Briefly describe the earth inductor compass.

Q3. What errors affect the compass?

Q4. What effect has variation on the compass?

Q5. How may the variation be found for a given locality?

Q6. How is variation named?

Q7. What effect has deviation on the compass?

Q8. How is deviation named?

Q9. How is a magnetic compass compensated for deviation?

Q10. Can the entire deviation be removed by compensation?

Q11. What is meant by swinging ship and how is it done?

Q12. How prepare a plane to swing ship?

Q13. How would you swing ship by reciprocal bearings?

Q14. When swinging ship, what are the principal points to be observed?

Q15. How are deviations found?

Q16. How are deviations recorded?

Q17. Give the rule for naming the deviation.

Q18. What is a deviation diagram or curve?

Q19. How swing ship on fixed ranges?

Q20. Does the earth inductor compass require a deviation table?

Q21. How often should a deviation table be checked? When would you expect the deviations to change?

Q22. What corrections must be applied to the true course, as found from the chart, to obtain the compass course?

Q23. What is leeway, set and drift?

Q24. How is the amount of leeway determined?

Q25. How is the leeway measured when in the air?

Q26. How are corrections applied to the true course to find the compass course?

Q27. What is a true course? A magnetic course? A compass?

Q28. What are the poles of the earth?

Q29. What is the equator?

Q30. What are the meridians?

Q31. What is the prime meridian?

Q32. What are latitude parallels?

Q33. What is latitude and how is it measured?

Q34. What is longitude and how is it measured?

Q35. How are latitude and longitude named?

Q36. What would be the latitude of a place half way between the equator and the north pole?

Q37. What would be the longitude of a place just half way around the earth from Greenwich, England?

Q38. What relation has longitude to time?

Q39. If it is exactly noon at A (the sun is on the meridian), what time is it at B, which is 75° west of A?

Q40. The sun is on the meridian at a place in longitude 60° west. What time is it in Greenwich? (Note: Greenwich is on the zero meridian).

Q41. What is a chart or map?

Q42. What conditions must be fulfilled to insure a true representation in chart or map making?

Q43. What methods are most commonly used in map and chart construction?

Q44. Briefly describe the Polyconic projection.

Q45. Briefly describe a Mercator projection.

Q46. What instruments are used in chart work?

Q47. What is a compass rose?

Q48. How would you find the true course and distance between two places shown on a chart or map of the Polyconic projection?

Q49. How would you find the true course and distance between two places shown on a chart or map of the Mercator projection?

Q50. What is the shortest distance between two places on the earth's surface?

Q51. How is the great circle track found?

Q52. How would you find the great circle track between two places by use of the great circle chart?

Q53. How find the course to steer when following a great circle track?

Q54. What causes wind to blow?

Q55. What causes clouds?

Q56. How are winds classified? Named?

Q57. What are the constant winds?

Q58. What are the periodical winds?

Q59. What are the variable winds?

Q60. What is a mercurial barometer?

Q61. What is an aneroid barometer?

Q62. What is meant by a high or low pressure area?

Q63. What causes changes of barometric pressure in a given locality?

Q64. What effect has atmospheric pressure on the wind?

Q65. How do atmospheric pressure waves move across North America and how is their progress recorded?

Q66. What is a weather map and how is it constructed?

Q67. Of what value is the weather map to the aviator?

Q68. What is a line squall?

Q69. What is a revolving storm?

Q70. What are the barometric indications of coming weather?

Q71. How may weather be foretold by the appearance of the sky?

Q72. What effect have barometric changes on the altimeter?

Q73. What causes bumps in the air?

Q74. What are storm warning flags and where are they displayed?

Q75. What are fractures and how are they classified?

Q76. What first-aid treatment should be given in fracture cases?

Q77. Of what should emergency splints be made?

Q78. How should splints be applied to a broken leg or arm?

Q79. How should a compound fracture be treated?

Q80. How should first-aid be rendered for fractures other than of the arms and legs?

Q81. How would you recognize a hemorrhage and how may it be stopped?

Q82. How is a tourniquet made and how should it be applied?

Q83. How revive a person that has been suffocated by the inhalation of poisonous gases, or by drowning?

Q84. How give first aid for burns and scalds?

Q85. What treatment should be given persons suffering from exposure to extreme cold?

Q86. What is a sprain and how is it treated?

Q87. What is a dislocation and how it is treated?

COURSE ERROR TABLE

Distance plane will be to right or left of destination due to error in course.

Miles	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°
10	.3	.7	1.1	1.4	1.8	2.2	2.5	2.9	3.3	3.7
20	.7	1.4	2 2	2.8	3.5	4.3	5.0	5.7	6.5	7.4
30	1.0	2.1	3.2	4.2	5.3	6.3	7.5	8.6	9.8	10.9
40	1.4	2.8	4.2	5.6	7.0	8.5	10.0	11.5	13.0	14.6
50	1.7	3.5	5.2	7.0	8.9	10.6	12.5	14.3	16.3	18.2
60	2.1	4.2	6.3	8.5	10.5	12.8	15.0	17.3	19.5	21.9
70	2.4	4.9	7.3	9.9	12.4	14.9	17.5	20.0	22.8	25.5
80	2.8	5.6	8.4	11.2	14.1	17.0	20.0	22.9	26.0	29.1
90	3.1	6.3	9.4	12.6	15.9	19.1	22.5	25.8	29.3	32.7
100	3.5	7.0	10.6	14.1	17.6	21.3	25.0	28.7	32.4	36.5
200	7.0	14.0	21.0	28.1	35.3	42.5	50.0	57.3	65.0	72.8
300	10.5	21.0	31.6	42.2	53.0	63.7	75.0	86.0	96.6	109.2
400	13.9	28.0	42.0	56.2	70.6	85.0	100.0	114.6	130.0	145.6
500	17.4	35.0	52.6	70.3	88.1	106.2	125.0	143.4	162.4	181.9

Nautical Miles	Statute Miles	Nautical Miles	Statute Miles	Nautical Miles	Statute Miles
1.00	1.151	8.75	10.075	16.50	18.999
1.25	1.430	9.00	10.363	16.75	19.287
1.50	1.727	9.25	19.651	17.00	19.575
1.75	2.015	9.50	10.939	17.25	19.863
2.00	2.015	9.75	11.227	17.50	20.151
2.25	2.303	10.00	11.515	17.75	20.439
2.50	2.590	10.25	11.803	18.00	20.727
2.75	2.878	10.50	12.090	18.25	21.015
3.00	3.166	10.75	12.378	18.50	21.303
3.25	3.454	11.00	12.666	18.75	21.590
3.50	3.742	11.25	12.954	19.00	21.878
3.75	4.030	11.50	13.242	19.25	22.166
4.00	4.318	11.75	13.530	19.50	22.454
4.25	4.606	12.00	13.818	19.75	22.742
4.50	4.893	12.25	14.100	20.00	23.030
4.75	5.181	12.50	14.393	20.25	23.318
5.00	5.469	12.75	14.681	20.50	23.606
5.25	5.757	13.00	14.960	20.75	23.893
5.50	6.045	13.25	15.257	21.00	24.181
5.75	6.333	13.50	15.545	21.25	24.469
6.00	6.621	13.75	15.833	21.50	24.757
6.25	6.909	14.00	16.121	21.75	25.045
6.50	7.484	14.25	16.409	22.00	25.333
6.75	7.772	14.50	16.696	22.25	25.621
7.00	8.060	14.75	16.984	22.50	25.909
7.25	7.196	15.00	17.272	22.75	26,196
7.50	8.348	15.25	17.560	23.00	26.484
7.75	8.636	15.50	17.560	23.50	27.060
8.00	8.924	15.75	17.848	24.00	27.636
8.25	9.212	16.00	18.136	24.50	28.212
8.50	9.500	16.25	18.424	25.00	28.787
	9.787		18.712		

Example: Convert 125 nautical miles into statute miles.

Solution: In column 1, take 1.25 nautical miles, move the decimal point two places right. Resulting statute miles 143.9 instead of 1.439.

Example: Convert 435 nautical miles into statute miles.

Solution: 425 nautical miles = 489.3 statute miles
10 nautical miles = 11.5 statute miles

435 nautical miles = 500.8 statute miles

Vancouver
Victoria
Bellingham
P. Townsend
Seattle
Tacoma
Olympia
Astoria
Vancouver
Portland
Empire
Eureka
Salt Lake City
UNITED STATE
Denver
Duluth
Oakland
S. Francisco
S. Jose
Monterey
S. Luis Obispo
Sta Barbara
Los Angeles
S. Diego
Yuma
LOWER CALIFORNIA
G. OF CALIFORNIA
Guadalupe I
(Mexico)
Guaymas
Alijos Rks
Magdalena B
La Paz
Altata
Mazatlan
MEXICO
San Blas
REVILLAGIGEDO IS.
(Mexico)
Clarion I
Manzanillo
MEXICO
Acapulco
Salina Cruz
Clipperton I
New Orleans
Galveston
Port Lavaca
Rockport
Brownsville
Matamoros
Tampico
Tuxpam
Vera Cruz
Progreso
Campeche
Carmen
Alvarado
Puerto Mexico
Frontera
GUATEMALA
SAN SALVADOR
(0′)
(−1′)
(−2′)
(−4′)
(+1′)
(+2′)
(+4′)
(+6′)
22°
24°
26°
28°
18°
20°
20°E
16°
14°
12°
10°
8°

A T L A N T I C O C E A N
30° W A
20° W A
10° W
NO VARIATION
Point de Monts
Mingan
Belle Isle
Tilt Cove
Anticosti
Caspe
GULF OF ST. LAWRENCE
NEWFOUNDLAND
Hearts Content
St. Johns
Tadoussac
Dalhousie
Amherst
St Paul I
Quebec
Montreal
OTTAWA
Sydney
St. Pierre (Fr.)
Miquelon (Fr.)
Canso
Toronto
ONTARIO
Belfast
Portland
Halifax
Sable I
Detroit
Buffalo
Albany
Portsmouth
Boston
Toledo
Cleveland
New Haven
Dunbury
Pittsburg
New York
Sandy Hook
Philadelphia
Wilmington
Baltimore
WASHINGTON
Newport News
Norfolk
Wilmington
Charleston
P. Royal
Savannah
Fernandina
St Augustine
St. Marks
Tampa
Pta Rasa
Key West
HABANA
Matanzas
Sagua la Grande
CUBA
Nuevitas
Gibara
Baracoa
Santiago
Clarence
Savannah la Mar
JAMAICA
Swan Is
Trujillo
Kingston
(P. Royal)
REPUBLIC OF HAITI
PORT AU PRINCE
DOMINICAN REP.
SANTO DOMINGO
Haitien
P. Plata
Sanchez
Porto Rico
S. Juan
Anguilla (Br.)
Antigua (Br.)
Dominica (Br.)
Martinique (Fr.)
St. Lucia (Br.)
Barbados (Br.)
Grenada (Br.)
Trinidad (Br.)
St Fernando
Tortuga
Margarita
Curaçao (Neth.)
Aruba
Guadeloupe (Fr.)
St Vincent
Blue fields
San Juan del Norte
Sta. Marta
Barranquilla
Cartagena
Puerto Cabello
CARACAS
Maracaibo
Panama
COSTA RICA
P. Limon
Colon
Perlas Is
CARIBBEAN SEA
VENEZUELA
COLOMBIA
Malpelo I (Colombia)
BOGOTA
Buenaventura
BERMUDA (Br.)
WEST INDIES
BAHAMA IS
Nassau
GEORGETOWN
New Amsterdam
PARAMARIBO
BRITISH
DUTCH
FRENCH
GUIANA
Cayenne
(+5′)
(+4′)
(+3′)
(+2′)
(+6′)
(0′)
(−5′)
(−6′)
(+9′)
34°
33°
32°
31°
28°
27°
26°
25°
24°
23°
22°
21°
19°
18°
17°
16°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
3°

GLOSSARY OF TERMS USED IN AERIAL NAVIGATION AND METEOROLOGY

There are a considerable number of technical terms employed in aviation, aerial navigation and meteorology that are not generally included in the vocabulary of the individual reader and student, so a list of such terms in common use with brief definitions is included in this treatise for reference. Not all aeronautical terms are defined, but only such as are employed in aerial navigation, airplane control or meteorology have been included. For a complete list of modern aviation terms the reader is referred to the report Number 240, Part I, entitled Standard Nomenclature for Aeronautics, prepared by the National Advisory Committee for Aeronautics, Washington, D. C. It is from this list that many of the definitions that follow have been taken.

Absolute Humidity. The actual amount of water vapor in the air.

Accelerometer. An instrument for indicating, measuring, or recording accelerations.

Agonic Lines. Lines joining separate points where the needle of the compass points true north and where magnetic variation is zero are known as agonic lines.

Air Log. An instrument for measuring the linear travel of an aircraft relative to the air. One form consists of a windmill with a revolution counter.

Airport. A locality, either of water or land, which is adapted for the landing and taking off of aircraft and which provides facili-

ties for shelter, supply, and repair of aircraft; or a place used regularly for receiving or discharging passengers or cargo by air.

Air Pressure. The air pressure at sea-level is 14.7 pounds per square inch on any surface against which it bears. Air pressure decreases with increasing altitude and varies with temperature. It is usually taken as 15 pounds per square inch, which simplifies calculations and is accurate enough for all practical purposes.

Air-speed Meter. Air-speed indicator—an instrument for indicating the speed of an aircraft relative to the air. It is actuated by the pressure developed in a suitable pressure nozzle or against a suitable obstruction and is graduated to give true air speed at a standard air density.

True Air-speed Meter. An instrument for measuring the true speed of an aircraft to the air. The Biram and Robinson anemometers are of this type.

Airway. An air route between air traffic centers which is over terrain best suited for emergency landings, with landing fields at intervals equipped with aids to air navigation and a communication system for the transmission of information pertinent to the operation of aircraft.

Altigraph. An altimeter equipped with a recording mechanism. Present instruments are of the aneroid type. The chart, driven by clockwork, is usually graduated in feet or meters in accordance with some empirical or arbitrary pressure-temperature-altitude formula. In other words, it is a barograph whose scale is designed to read heights.

Altimeter. An instrument for measuring or indicating the elevation of an aircraft above a given datum plane.

Altimeter, Aneroid. An altimeter, the indications of which depend on the deflection of a pressure-sensitive element. The graduations of the dial correspond to an empirical or arbitrary pressure-temperature-altitude formula.

Altimeter, Electrical-capacity. An altimeter, the indications of which depend on the variation of an electrical capacity with distance from the earth's surface.

Altimeter, Engine. An altimeter for indicating the altitude corresponding to the pressure produced in the intake manifold of a supercharged engine.

Altimeter, Optical. An altimeter, the indications of which depend on the manipulation of a suitable optical system.

Altimeter, Sound-ranging. An altimeter, the indications of which depend on the measurement of the time required for a sound wave to travel from the aircraft to the earth and back.

Anemometer. An instrument for indicating or measuring the speed of an air stream.

Angle, Critical. An angle of attack at which the flow about an airfoil changes abruptly with corresponding abrupt changes in the lift and drag.

Angle, Downwash. The angle through which an air stream is deflected by any lifting surface of an airplane. It is measured in a plane parallel to the plane of symmetry and is denoted by the symbol e.

Angle, Drift. The horizontal angle between the longitudinal axis of an aircraft and its path relative to the ground.

Angle, Elevator. The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

Angle, Landing. The acute angle between the line of thrust of an airplane and the horizontal when the airplane is resting on level ground in its natural position. Also called "ground angle."

Angle, Minimum Gliding. The acute angle between the horizontal and the most nearly horizontal path along which an airplane can descend steadily in still air when the propeller is giving no thrust.

Angle of Attack. The acute angle between the chord of an aerofoil and its direction of motion relative to the air. (This definition may be extended to other bodies than aerofoils.)

Angle of Pitch. The acute angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is the angle between the longitudinal axis and the direction of the relative wind.)

Angle of Roll, or Angle of Bank. The acute angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane. This angle is denoted by ϕ and is positive when the left wing is higher than the right.

Angle of Stabilizer Setting. The acute angle between the line of thrust of an airplane and the chord of the stabilizer.

Angle of Wing Setting. The acute angle between the plane of wing chord and the line of thrust. It may differ for each wing.

Angle of Yaw. The acute angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is denoted by ψ and is positive when the aircraft has turned to the right.

Angle, Rudder. The acute angle between the rudder and the plane of symmetry of the aircraft. It is positive when the trailing edge has moved to the left with reference to the normal position of the pilot.

Anti-cyclone. The air of high atmospheric pressure which travel is accompanied by clear and calm weather.

Atmosphere. A combination of gases, principally oxygen and nitrogen, that we know as air that surrounds the earth, forming a blanket that has been estimated to be 40 miles to several hundred miles in depth.

Attitude. The position of an aircraft as determined by the inclination of its axes to some frame of reference. If not otherwise specified, this frame of reference is fixed to the earth.

Axis. The diameter of a sphere passing through the North and South poles. The imaginary line representing an axle about which the earth is supposed to rotate, passing through the center of the earth and joining the poles.

Axes of an Aircraft. Three fixed lines of reference, usually centroidal and mutually perpendicular. The longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. In mathematical discussions, the first of these axes, drawn from front to rear, is called the X axis; the second, drawn upward, the Z axis; and the third, running from right to left, the Y axis.

Balanced Surface. A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge.

Bank. To incline an airplane laterally, i.e., to rotate it about its longitudinal axis. Right-bank is to incline the airplane with the right wing down.

Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

Barograph. An instrument for recording the barometric or static pressure of the atmosphere.

Bearing. The angle measured in a clock-wise direction from a fixed line to any point distinct from and away from that line.

Bearing, True. The measurement from the true meridian to any distant point. The angle is measured clock-wise.

Bearing, Magnetic. The measurement of angle from the

magnetic meridian to any point distinct from and away from that line.

Bearing, Reciprocal. The bearing taken from the position of the observer to an object in the distance. This is expressed as the bearing from an object to the observer and is equal to the forward bearing plus 180°.

Bearing, Mercatorial. This is an angle between the meridian at which the observer is and a line joining him to the object.

Bearing Plate. Bearings of distant objects may be calculated on drift and ground speed obtained by using this instrument.

Bumps. In aerial navigation, points where an ascending current is adjacent to a descending current. This forms what is erroneously termed "air-pockets" and causes a fluctuation in the flight path of the plane. If the air current is rising from the heated earth it is known as a "ground bump" but if the heat is reflected from the clouds it is known as a "cloud bump."

Camber. The rise in the curve of an aerofoil section from its chord, usually expressed as the ratio of the departure of the curve from the chord to the length of the chord. "Upper camber" refers to the upper surface of an aerofoil and "lower camber" to the lower surface; "mean camber" is the mean of these two.

Ceiling, Absolute. The maximum height above sea level at which a given airplane would be able to maintain horizontal flight, assuming standard air conditions.

Ceiling, Service. The height above sea level, assuming standard air conditions, at which a given airplane ceases to be able to rise at a rate higher than a small specified one (100 feet per minute in the United States and England). This specified rate may be different in different countries.

Ceiling, Static. The altitude in standard atmosphere, at which an aerostat is in static equilibrium after removal of all dischargeable weights.

Circles. The degree of latitude and degree of longitude forms a square the sides of which measure 60 minutes. At 60° north or south, while the north and south line measures 60 minutes, the east and west line measures less than that amount. It will be evident that as the circumference of the circle is reduced, the distance representing 1° is reduced in proportion.

Circles, Great. Any circle having a plane passing through the center of a sphere to divide it into equal parts. The equator is an example of a great circle.

Circles, Small. When a plane does not pass through the center of the sphere the circle is said to be a small circle. All parallels of latitude are small circles except the equator. The small circles become reduced in size as they approach the poles.

Chart. A graphic plan or representation of any portion of the earth's surface showing more water than land, used by mariners or seaplane pilots.

Clouds. A visible condensation of water vapor above the Earth's surface.

Compass, Rose. A dial having graduated circles which are printed on a chart indicating true North and magnetic North.

Contours. Any imaginary line running at the same height above sea-level throughout its length along the surface of the ground.

Contour Maps. Maps upon which various heights of hills and mountains are represented by contour lines, tints or conventional hatchures.

Convection. The transfer of heat from one point to another by circulation. Warm air rises and cool air takes its place. Rapid air movements are known as winds.

Conventional Signs. Marking on a map or chart showing features of importance, such as rivers, railroads, forests, lakes, etc.

Conversion Angle. The angle between the great circle and the rhumb line that is employed in using directional wireless.

Cockpit. The open spaces in which the pilot and passengers are accommodated. When the cockpit is completely housed in, it is called a cabin.

Compartment, Control. A compartment in the control car of an airship from which all controls are operated. It may be compared to the pilot house of a ship.

Compass, Induction. A compass, the indications of which depend on the current generated in a coil revolving in the earth's magnetic field.

Controllability. The quality in an airplane which makes it possible for the pilot to change its attitude easily and with the exertion of but little force.

Controls. A general term applied to the means provided to enable the pilot to control the speed, direction of flight, attitude, altitude and power of an aircraft.

Controls, Air. The means employed to operate the control surfaces of the aircraft.

Controls, Engine. The means employed to control the power output of the engines. (Control of speed may be effected by the air controls or the engine controls independently, or by either in conjunction with the other.)

Control Stick. The vertical lever by means of which the longitudinal and lateral controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by a side-to-side movement.

Cyclone. The area of low pressure where the temperature is lower than in the surrounding parts. This is usually accompanied by rain storms.

Datum or Datum Level. Any height above sea-level or below it to which altitude and surrounding objects are referred.

The usual datum level is sea-level but in navigating over mountains surrounding a high plateau the height of the plateau might be taken as a datum level.

Dead Reckoning. Calculations to determine position which depend on data given by instruments such as the compass, or the air speed indicator, and that are not verified by observations of terrestrial or celestial objects.

Degree. A degree is a 360th part of a circle, it is divided into 60 minutes and each minute is further subdivided into 60 seconds. Positions on a map or chart are determined and expressed as so many degrees east of the prime meridian and North or South of the equator.

Deviation. Deviation is caused by the effect of permanent and induced magnetism of the airplane frame or other steel and iron parts on the compass needle.

Dive. A steep descent, with or without power, in which the air speed is greater than the maximum speed in horizontal flight.

Divergence. A motion in which, after a disturbance from equilibrium, the body departs continuously, without oscillations, from its original state of motion.

Drift. The lateral velocity of an aircraft due to air currents.

Drift Bar. A part of a drift meter or other instrument for indicating the apparent direction of motion of the ground relative to the fore-and-aft axis of the aircraft. It usually consists of a wire or arm which can be set along the direction of motion. *Cf.* drift.

Drift Meter. An instrument for measuring the angle between the fore-and-aft axis of an aircraft and its path over the ground. One form consists of a drift bar provided with a suitable angular scale. (*Cf.* drift.) The instrument is graduated to read correctly when it is level.

Ecliptic. A great circle in the heavens that the sun appears to describe in a year. This is really caused by the orbit of the earth which revolves around the sun which is fixed and the center of our solar system.

Elevator. A movable auxiliary aerofoil, the function of which is to impress a pitching moment on the aircraft. The elevator is usually hinged to the stabilizer.

Endurance. The maximum length of time an aircraft can remain in the air at a given speed and altitude.

Equator. An imaginary line on the earth's surface around its circumference half way between the South and North Poles and dividing the earth into Southern and Northern Hemispheres.

Factor of Safety. The ratio of the ultimate strength of a member to the maximum probable load on that member in actual use.

Fin. A fixed surface, attached to a part of the aircraft, parallel to the longitudinal axis, in order to secure stability; for example, a tail fin, skid fin, etc. Fins are sometimes adjustable.

Fire Wall. A fire-resisting transverse bulkhead, usually of metal so set as to isolate the engine compartment from the other parts of the structure and thus to reduce the risk from fire in the engine compartment.

Fitting. A generic term for any small part used in the structure of an airplane or airship. If without qualification, a metal part is usually understood. It may refer to other parts, such as "fabric fittings."

Fix. When two or more position lines or bearings intersect on a chart or map the point of intersection is called a Fix.

Flight, Cross-country. A flight which necessitates leaving the vicinity of a regular landing field.

Flight Path. The path of the center of gravity of an aircraft with reference to the earth.

Fog. A cloud in contact with the earth caused by the temperature becoming lower than the dew point.

Force, Cross-wind. The component, perpendicular to the lift and to the drag, of the total air force on the aircraft or any part thereof. Its symbol is C and its absolute coefficient is C_c as defined by

$$C_c = \frac{C}{qS}$$

where q is the impact pressure ($= \frac{1}{2} p V^2$) and S is the effective area of the surface upon which the air force acts.

Fuel (or Oil) Consumption, Specific. The weight of fuel (or oil) consumed per brake horsepower hour.

Glide. A descent with reference to the air at a normal angle of attack and without engine power sufficient for level flight in still air, the propeller thrust being replaced by a component of gravity along the line of flight. Also used as a verb.

Gnomonic Projection. If arcs of Great Circles on the sphere are indicated as straight lines on the chart such as employed in long distance navigation, such projection is known as "gnomonic."

Ground-speed meter. An instrument for measuring the speed of an aircraft relative to the ground. In present types of instruments some reference line in the instrument must first be set parallel to the apparent direction of motion of the aircraft with reference to the ground before the speed measurement is made. This is usually accomplished by the use of a drift meter, the adjustment of which automatically orients the ground-speed meter properly. Thus both the magnitude and direction of the motion of the aircraft with reference to the ground are obtained.

Hatchures. Shade lines drawn on a map or chart in the direction of supposed inclination that help to give the contour of the ground.

Head Wind. Any wind blowing parallel to the line of flight. Heads winds are always retarding winds and reduce the ground speed of an airplane, but not its air speed.

Hangar. A shelter for housing aircraft. More properly applied to buildings for heavier-than-air craft.

Height, Pressure. The altitude at which the gas cells of a rigid airship are full, or the gas bag of a non-rigid airship is completely full of gas.

Horsepower of an Engine, Maximum. The maximum horsepower which an engine can develop.

Horsepower of an Engine, Rated. The average horsepower developed by an engine of a given type in passing the standard 50-hour endurance test.

Inclinometer. An instrument for indicating the attitude of an aircraft. Inclinometers are termed fore-and-aft, lateral, or universal, according as they indicate inclination on the vertical plane through the fore-and-aft axis, or in the vertical plane through the lateral axis, or in both planes, respectively.

Inclinometer, Absolute. An instrument which indicates the attitude of an aircraft with reference to the vertical. The indications of instruments of this type usually depend on gyroscopic action.

Inclinometer, Relative. An instrument which indicates the attitude of an aircraft with reference to apparent gravity, i.e., to the resultant of the acceleration of the aircraft and that due to gravity.

Indicator, Flight. An instrument in which a lateral inclinometer, a fore-and-aft inclinometer, and a turn indicator are combined to form a compact unit.

Indicator, Gyroscopic Turn. A turn indicator dependent on gyroscopic action.

Indicator, Pitch. An instrument for indicating the existence of a pitching velocity of an aircraft. *Cf.* turn indicator.

Indicator, Static Turn. A turn indicator actuated by the difference in pressure between static tubes mounted near the wing tips equidistant from the plane of symmetry, and in a plane parallel to the lateral axis.

Indicator, Turn. An instrument for indicating the existence of an angular velocity of turn of an aircraft about the normal axis. In horizontal flight it indicates the presence of a yawing velocity. "Turn meter" is the term applied to certain types.

Isobars. Lines connecting points having the same atmospheric pressure.

Isotherms. Lines connecting all points on the Earth's surface having equal temperatures.

Isogonic Lines. Places where the magnetic variation of the compass is equal, are joined by such lines.

Intersection. Point where two or more position lines meet or cross each other.

Kymograph. An instrument for recording the angular oscillations of an aircraft in flight with respect to axes fixed in space. The reference direction is usually given by a gyroscope or a beam of sunlight.

Landing Field. A field of such a size and nature as to permit of aircraft landing and taking off in safety. It may or may not be part of an airport.

Landing Field, Emergency. A locality, either of water or land, which is adapted for the landing and taking off of aircraft, but which is not equipped with facilities for shelter, supply, and repair of aircraft and is not used regularly for the receipt or discharge of passengers or cargo by air.

Landing T. A large symbol shaped like a capital T which is laid out on a landing field or on the top of a building to guide

operators of aircraft in landing and taking off. It is changed in position with each change in wind direction.

Latitude. The arc of the meridian intercepted between the place and the equator. Latitude is measured in degrees, minutes and seconds up to 90° North or South of the equator.

Legend. The key printed on a map or chart giving the explanation of the conventional signs used thereon to show natural features or works of man.

Lift. That component of the total air force on an aircraft or aerofoil which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or to parts thereof. In the case of an airship, this is often called "dynamic lift." Its symbol is L.

The "absolute lift coefficient" is C_L as defined by the equation

$$C_L = \frac{L}{qS}$$

in which L is the lift, q is the impact pressure ($= \frac{1}{2} p V^2$) and S is the effective area of the surface upon which the air force acts.

Lift, Dynamic. The lift impressed on an aerostat by aerodynamic forces.

Lift, Gross (Airship). The lift obtained from a volume of buoyant gas equal to the nominal gas capacity of the aircraft. Obtained by multiplying the nominal gas capacity by the lift per unit volume of the gas used for inflation.

Lift, Static (Aerostat). The resultant upward force on an aerostat at rest obtained by multiplying the actual volume of the air displaced by the density of the air and subtracting the weight of the contained gas.

Lift, Useful (Airship). The lift available for carrying fuel, and oil, passengers, cargo, food, and drinking water, guns, ammunition, and bombs. Usually determined by deducting from

the gross lift all fixed weights; certain allowances of ballast, fuel, and oil; water; spares and tools; crew and equipment. No standard has as yet been established.

Line Squall. A very rapid air movement or high wind accompanied by a long line of very dark clouds with violent rain or hail.

Load, Dead. See weight, empty.

Load, Full. Weight empty, plus useful load. Also called "gross weight."

Load, Pay. That part of the useful load from which revenue is derived, viz., passengers and freight.

Load, Useful. The crew and passengers, oil, and fuel, ballast other than emergency, ordnance, and portable equipment.

Load, Basic. The load on an aircraft when it is at rest or in a condition of accelerated recti-linear flight. (For purposes of stress analysis.)

Load, Dynamic. Any load due to accelerations of an aircraft, and therefore proportional to its mass.

Load Factor. The ratio of any specified load on a member to the corresponding basic load. Generally applied to the ratio of the breaking load to a basic load.

Loading, Power. The gross weight of an airplane, fully loaded, divided by the normal brake horsepower of the engine computed for air of standard density (unless otherwise stated).

Loading, Wing. The gross weight of an airplane, fully loaded, divided by the area of the supporting surface. The area used in computing the wing loading should include ailerons, but not the stabilizer and elevators.

Longitude. The arc of the equator intercepted between the meridian and the observer's position and the prime meridian. It is also measured in degrees, minutes and seconds up to 180° East and West of the prime meridian.

Lubber Line. The mark on the compass face indicating the direction of the head of the aircraft in relation to the direction of the north-seeking end of the compass needle or card.

Magnetic Variation. The angle between true and magnetic meridians. Variations are known as East or West according to whether the magnetic needle points East or West of the true meridian.

Magnetic Attraction, Local. Presence of large masses of iron or nickel ore in some localities produce deviation of the magnetic lines of force of the earth so that the compass may be rendered practically useless at that locality.

Magnetic Poles. At the North Magnetic pole the magnetic attraction is known as blue magnetism and at the South pole as red magnetism.

Mercator's Projection. Charts employed in Navigation which employ the projection where all meridians are indicated as straight lines at right angles to the parallels of latitude which are also indicated as parallel lines.

Meridian. This is a great circle on the earth's surface passing through the North and South Poles.

Meridian, Prime. This is a Meridian at which Greenwich, England, is located, which most countries accept as the basis for calculating longitude for navigation purposes.

Map. A graphic representation of any portion of the earth drawn to scale in which the amount of land is greater than the amount of water. Maps are used by navigators of airplanes and for overland travel.

Map, Scale of. All maps are drawn to scale which means that a certain distance on the map represents a proportionately large distance on the earth's surface. Scale is often expressed as ¼" (on the map) to 1 mile (on the earth), and may be indicated by scales in the corner of the map or chart.

Navigation Lights. All airplanes used at night must carry port, starboard, and tail lights.

Nose-heavy. The condition of an airplane in normal flight when the distribution of forces is such that, if the longitudinal controls were released, the nose would drop.

Nozzle, Pressure. An instrument which, in combination with a gauge, is used to measure the indicated speed of an aircraft relative to the air. It may be a Pitot tube or a Venturi tube, or a combination of a Pitot tube and a Venturi tube.

Orienting. Placing the map in such a way that the north line on the map points North.

Oscillation, Phugoid. A long-period oscillation characteristic of the disturbed longitudinal motion of an aircraft. This is referred to when it is said that an aircraft "hunts."

Oscillation, Stable. An oscillation whose amplitude does not increase.

Oscillation, Unstable. An oscillation whose amplitude increases continuously until an attitude is reached from which there is no tendency to return toward the original attitude, the motion becoming a steady divergence.

Pancake, to. To level off an airplane at a greater altitude than normal in a landing, thus causing it to stall and to descend on a steeply inclined path with the wings at a very large angle of attack and without appreciable bank.

Pendant, Sighting. A vertical wire on center line and forward of the control car of an airship, used as a mark in steering, to assist in determining wind direction.

Periodic Winds. Air movements which are not caused by convection or ordinary circulation of the atmosphere.

Pitot Tube. A cylindrical tube with an open end which is pointed upstream (i.e., so that the air meets the instrument

head-on or is met head-on by the instrument). When the aircraft is flying less than about 200 miles per hour, the instrument measures the impact pressure. When used on aircraft, it is usually associated either with a closed coaxial tube surrounding it or with a closed tube placed near it and parallel to it, the combination being termed a Pitot-static tube. The associated tube has perforations in its side so that it is subjected to static pressure, as distinct from impact pressure. The speed of the fluid can be determined from the difference between the impact pressure and the static pressure as read by a suitable gauge. In common terminology the Pitot-static combination, as above, is often termed simply a Pitot tube or Pitot.

Planetary Winds. Air movements caused by the rotation of the earth from West to East.

Poles. The North and South poles are the two points at which the imaginary axis of the earth comes to the surface.

Position Line. The line obtained by observation on some landmark or star, somewhere on the line it is known that the craft must be. The sun is the favorite celestial object for determining position in daytime and Polaris or the North Star at night.

Prevailing Winds. Winds blowing always from one direction the greater part of the year.

Precipitation. The return to the Earth of any constant moisture in the form of rain, sleet, hail or snow. These different forms of water depend on the temperature of the air through which the precipitation passes.

Pressure, Manometer (Aerostat). The excess of pressure inside the envelope of an aerostat over the atmospheric pressure at a standard reference point. The point of reference for the excess of pressure is usually the bottom of the envelope or gas cell for airships and the level of the basket for kite balloons.

Propeller, Adjustable Pitch. A propeller whose blades are so attached to the hub that they may be set to any desired pitch when the propeller is stationary.

Propeller, Controllable Pitch or Variable Pitch. A propeller whose blades are so mounted that they may be turned about their axes to any desired pitch while the propeller is in rotation.

Propeller Area, Projected. The total area in the plane perpendicular to the propeller shaft swept by the propeller, excepting the portion covered by the boss and that swept by the root of the blade. This portion is usually taken as extending 0.2 of the maximum radius from the axis of the shaft.

Propeller Interference. The amount by which the torque and thrust of a propeller are changed by the modification of the airflow in the slipstream produced by bodies placed near the propeller, such as engine, radiator, etc.

Propeller-Load Curve. A curve representing the engine power necessary to drive any given propeller at various speeds. The power required varies approximately as the cube of the speed in R.P.M., provided the ratio $\frac{V}{ND}$ remains constant.

Propeller Thrust. The component parallel to the propeller axis of the total air force on the propeller. Its symbol is T.

Propulsive Efficiency. The ratio of the product of effective thrust and flight speed to the actual power input to the propeller as mounted on the airplane, consistent units being used throughout.

Quadrant. The operating lever, made on the arc of a circle, of a control surface of an airship, e.g., rudder quadrant, elevator quadrant.

Range at Economic Speed. The maximum distance a given

aircraft can cover while cruising at the most economical speed and altitude at all stages of the flight.

Range at Full Speed. The maximum distance a given aircraft can cover at full speed at sea level.

Rate of Climb. The vertical component of the air speed of an aircraft, i.e., its vertical velocity with reference to the air.

Recorder, Flight. An instrument for recording certain elements of the performance of an aircraft.

Relative Humidity. The actual amount of water vapor present in the air compared to the amount which the same volume of air contains when it is saturated.

Rhumb Line. The rhumb line is that intersecting or cutting through the meridians that it crosses at the same angle. In the absence of any wind it is the track of an airplane steering a true course. All straight lines on Mercator's Projection are "rhumb" lines. It is sometimes spelled "rumb."

Revolutions, Maximum. The number of revolutions per minute corresponding to the maximum horsepower.

Revolutions, Rated. The number of revolutions corresponding to the rated horsepower.

Righting Moment (or Restoring Moment). A moment which tends to restore an aircraft to its previous attitude after any small rational displacement.

Roll. A maneuver in which a complete revolution about the longitudinal axis is made, the horizontal direction of flight being approximately maintained.

Rudder Torque. The twisting moment exerted by the rudder on the fuselage. The product of the rudder area by the distance from its center of area, the axis of the fuselage, may be used as a relative measure of rudder torque.

Ship. Slang for an airplane. In view of the confusion with "airship" it should not be used.

Side Slipping. Flight in which the lateral axis is inclined and the airplane has a component of velocity in the direction of the lower end of the lateral axis. When it occurs in connection with a turn, it is the opposite of skidding (q.v.).

Skidding. Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently and is the opposite of side slipping (q.v.).

Skid Fin. A fore-and-aft vertical surface, usually placed above the upper wing, designed to provide vertical keel surface and so to increase lateral stability.

Sky Writing. The act of emitting from an aircraft a trail of smoke or other visible substance, the flight of the aircraft being so directed as to cause the trail to assume the form of letters or symbols.

Slip. The difference between the mean geometrical pitch of a propeller and the effective pitch. Slip may be expressed as a percentage of the mean geometrical pitch or as a linear dimension.

Slipstream. The stream of air driven astern by the propeller. (The in-draft is sometimes included also.)

Soar. To perform sustained free flight without self-propulsion; it is called "up-current soaring" if performed in ascending air; "dynamic soaring" in other cases.

Specific Fuel (or Oil) Consumption. See fuel (or oil) consumption, specific.

Speed, Critical. The lowest flying speed of an aircraft at which control can be maintained. Below this speed, the controls become ineffective and wings have insufficient lift.

Speed, Economic. The speed at which the fuel-consumption, per unit of distance covered in still air, is a minimum.

Speed, Ground. The horizontal component of the velocity of an aircraft relative to the earth.

Speed, Landing. The minimum speed at which an airplane

can maintain itself in level flight and still be under adequate control.

Speed, Minimum. The lowest steady speed which can be maintained by an airplane in level flight at an altitude large in comparison with the dimensions of the wings, with any throttle setting whatever.

Sphere. A solid body having a round surface, every point of which is at the same distance from the center. The earth is a sphere, slightly flattened at the poles.

Spin. A maneuver consisting of a combination of roll and yaw, with the longitudinal axis of the airplane inclined steeply downward. The airplane descends in a helix of large pitch and very small radius, the upper side of the airplane being on the inside of the helix, and the angle of attack on the inner wing being maintained at an extremely large value.

Spot Height. Points on a map with the exact elevation above sea-level printed thereon.

Stability. That property of a body which causes it, when disturbed from a condition of equilibrium or steady motion, to develop forces or moments which tend to restore the body to its original condition.

Stability, Automatic. Stability dependent upon movable control surfaces automatically operated by mechanical means.

Stability, Inherent. Stability of an aircraft due solely to the disposition and arrangement of its fixed parts, i.e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of controls or the interposition of any mechanical devices.

Stability, Static. Stability of such a character that, if the airplane is displaced slightly from its normal attitude by rotation about an axis through its center of gravity (as may be done in

wind tunnel experiments), moments come into play which tend to return the airplane toward its original attitude.

Stability, Dynamic. Stability of such a character that, if the airplane is displaced from steady motion in flight, it tends to return to that steady state of motion, the oscillations due to restoring moments being damped out.

In a general way, the difference between static stability and dynamic stability is that the former depends on restoring moments alone, while the latter includes the action of damping factors.

Stability, Longitudinal. Stability with reference to disturbances in the plane of symmetry, i.e., disturbances involving pitching and variation of the longitudinal and normal velocities.

Stability, Directional. Stability with reference to rotations about the normal axis, i.e., an airplane possesses directional stability in its simplest form if a restoring moment comes into action when it is given a small angle of yaw. Owing to symmetry, directional stability is closely associated with lateral stability.

Stability, Lateral. Stability with reference to disturbances involving rolling, yawing, or side slipping, i.e., disturbances in which the position of the plane of symmetry of the aircraft is affected.

Stability, Spiral Instability. A type of instability inherent in certain airplanes which becomes evident when the airplane, as a result of a yaw, assumes too great a bank and side slips; the bank continues to increase and the radius of the turn to decrease.

Stabilizer. A normally fixed aerofoil whose function is to lessen the pitching motion. It is usually located at the rear of an aircraft and is approximately parallel to the plane of the longitudinal and lateral axes. Also called "tail plane."

Stabilizer, Mechanical. A mechanical device to prevent an

aircraft from departing from a condition of steady motion, or, in case such a motion is disturbed, to restore it to its steady state. Includes gyroscopic stabilizers, pendulum stabilizers, inertia stabilizers, etc.

Stall. The condition of an airplane when from any cause it has lost the air speed necessary for support or control.

Statoscope. An instrument for detecting minute changes of altitude of an aircraft. The indications of the instrument usually depend on small changes of the static pressure of the air.

Stratosphere. The upper region of the atmosphere where extreme weather prevails and where there is practically no wind. Man has only penetrated the extreme lower limits of this region.

Streamline. The path of a small portion of a fluid relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such flows as are not eddying, but the distinction should be made clear by the context.

Streamline Flow. Steady flow past a solid body, i.e., a flow in which the direction at every point is independent of time.

Supercharger. A mechanical device for supplying the engine with a greater weight of charge than would normally be induced at the prevailing atmospheric pressure and temperature.

Surface, Control. A movable aerofoil designed to be rotated or otherwise moved by the pilot in order to change the attitude of the airplane or airship.

Surface, Main Supporting. A set of wings, extending on the same general level from tip to tip of an airplane; e.g., a triplane has three main supporting surfaces. The main supporting surfaces include the ailerons, but no other surfaces intended primarily for control or stabilizer purposes.

Synoptic Chart. A map showing the weather for any region at a given time.

Tail Wind. A wind blowing parallel to the line of flight aiding the aircraft and increasing the ground speed of the airplane.

Tank, Fixed Fuel. A fuel tank which is not intended or fitted to be dropped, as "slip" tanks are.

Tank, Service. A fixed fuel tank near each power unit, into which fuel from other tanks is pumped and from which the fuel supplying the engines is drawn.

Tank, Slip Fuel. A fuel tank which is provided with a device permitting the quick dropping of the tank and contents as a whole in case of an emergency. Fitted on both airships and airplanes.

Taxi. To run an airplane over the ground, or a seaplane on the surface of water under its own power.

Testing Performance. The process of determining performance characteristics.

Thermograph. An instrument for recording temperature.

Thrust, Effective. The net driving force delivered by a propeller when mounted on an airplane, i.e., the actual thrust given by the propeller, as mounted on an airplane, minus any increase of resistance of the airplane produced by the action of the propeller.

Track. A line on a map or chart along which any craft is traveling is known as a track.

Track Angle. The angle between the track and the true meridian measured clock-wise up to 360° from the meridian.

Transit. When two objects distant from each other and from the observer appear to be on a line with him they are said to be in transit. The instrument used for measuring lines is also called a "transit."

Trim. The attitude of an aerostat relative to a fore-and-aft horizontal plane. If the forward end is down, the aerostat is

said to have "trim by the bow"; if the after end, it has "trim by the stern."

Trim, To. To alter the attitude of an aerostat relative to a fore-and-aft horizontal plane. If the endeavor is to force the bow down, the aircraft is "trimmed by the bow"; if the stern, it is "trimmed by the stern." If the aircraft shows a tendency to sink by the bow end, it is said to "trim by the bow" or to be "bow-heavy"; if the tendency is to sink by the stern it is said to "trim by the stern" or to be "stern-heavy."

Trim, Dynamic. Trim (or trimming) due to dynamic conditions or their change.

Trim, Static. Trim (or trimming) due to static conditions or their change

Troposphere. This is the part of the atmosphere that we are most familiar with and in which practically all aircraft are flown. It is the area of storms and varying weather and that portion below the tropopause nearest the earth.

Tropopause. An imaginary line dividing the atmosphere into lower and upper portions or regions.

Turn, Reverse. A rapid maneuver to reverse the direction of flight of an airplane, made by a half loop and half roll.

Venturi, Power. A Venturi tube used to operate gyroscopic turn indicators and other instruments.

Venturi, Speed-indicating. A Venturi tube may be combined with a Pitot tube or with a tube giving static pressure to form a pressure nozzle which may be used to determine the indicated speed of an aircraft through the air. The pressure difference is measured by a suitable gauge.

Venturi Tube. A short tube with flaring ends and a narrow or constricted section between them, into which a side tube opens. When fluid flows through the Venturi, there is a reduction of

pressure in the constricted section, the amount of reduction being a function of the velocity of flow.

Vertical Interval. This is any elevation shown by the space between contour lines on a map.

Vertimeter. A device for indicating the rate of rise and fall of an aerostat, usually a special form of statoscope. A rate-of-climb meter serves the same purpose, although of a different form.

Wash. The disturbance in the air produced by the passage of an aerofoil. Also called the "wake" in the general case for any solid body, such as a boat hull in water.

Washin. Permanent warping of the wing which results in an increase in the angle of attack near the tip.

Washout. Permanent warping of a wing which results in a decrease in the angle of attack near the tip.

Weight, Dischargeable (Consumable Weight) (Airship). All weight which can be consumed or discharged and still leave the airship in safe operating condition with a specified reserve of fuel, oil, water ballast, and provisions, and her normal crew.

Weight, Disposable (Airship). All weight other than fixed weights, including dischargeable weights contrasted with fixed weights, q.v.

Weight, Empty. The structure, power plant, and fixed equipment of an aircraft. Included in this fixed equipment are the water in the radiator and cooling system, all essential instruments and furnishings, fixed electric wiring for lighting, heating, etc. In the case of the aerostat the amount of ballast which must be carried to assist in making a safe landing must also be included.

Weight, Fixed (Airship). The weight of the hull machinery and all equipment and parts which are fixed in position and nonconsumable. All constant and nonconsumable weights which

an airship would carry under all conditions of service (British). Liquids in cooling systems of engines are included.

Weight, Fixed Power Plant, for a Given Airplane. The weight of an engine, including ignition, carburetor, and induction systems complete, propeller and hub, exhaust manifolds, radiator and water, if used, with all interconnecting wires, controls, tanks, and pipes, lubricating oil temperature regulators, the oil contained in the engine crankcase and the starting gear attached to the engine, but excluding fuel, oil, and engine instruments.

Weight per Horsepower. The dry weight of an engine divided by the rated horsepower.

Windmill. An air-driven screw used to drive auxiliary apparatus on an aircraft.

Wind. Motion of the air because of convection produced by unequal warming of different parts of the Earth by the sun. Winds are always stronger during the day time than they are at night.

Wind, Relative. The motion of the air with reference to a body, i.e., its motions as observed by a man at rest on the body. The direction and velocity of the relative wind, therefore, are found by adding two vectors, one being the velocity and the air with reference to the earth, the other being equal and opposite to the velocity of the body with reference to the earth.

Wing-heavy. The condition of an airplane in which (in normal flight) there is a tendency for the right (or left) wing to drop, if the lateral control is released, i.e., the condition in which the pilot has to exert a lateral force on the control stick to keep the lateral axis horizontal.

Zoom. To climb for a short time at an angle greater than that which can be maintained in steady flight, the airplane being carried upward at the expense of its kinetic energy. This term is sometimes used as a noun, to denote any sudden increase in the upward slope of the flight path.

INDEX

A

PAGE

Absolute Humidity 169
Accident Reports 242
Acid Burns 212
Acrobatic Flying 262
Aerial Navigation Maps 31
Agonic Lines 60
Air Commerce Regulations 216
  Composition of 163
Aircraft Belonging to States 219
  Operations Requiring a License 218
Air Flow Direction 167
Airplane Compass 48
  Drift 112
  Fuselage a Magnet 67
  Lights 264
Airship Lights 264
Air Traffic Rules 260
  Trails, Maps of 32
  Weight of 163
Airworthiness, Law of 220
  Meaning of 221
  Requirements 221
Altering Course 262
Altimeter Readings 184
  Readings, Allowances for 138
  Pressure and Temperature Table 185
Alto-Cumulus Clouds 193
  Stratus Clouds 193
Aneroid Barometer 163
Angle, Definition of 1
  of Drift 114
Application for Aircraft License 234
  for Pilots' Licenses 248
  of Air Traffic Law 260
  of Mechanics' License Law 258
Approaching, Rule for 261
Approved Type Certificate, Requirements for 231
Artificial Magnets 45
  Respiration 210

PAGE
Anti-Cyclone Area 167
Average Deviation of Upper Air Winds in Summer 187
of Upper Air Winds in Winter 189
Axis, Magnetic 45
of the Earth 45

B

Balloon Lights 264
Barometer, Aneroid 163
Mercurial 163
Readings as Weather Index 181
Gradient 168
Tide 180
Beacon, Radio 148
Bearing and Direction Examples 9
Indicators 34
of an Object 4
Plate 92
Points, Port 14
Starboard 13
Relative 12
Beaufort Wind Scale 177
Blind Flying 145
Bowl of Compass 50
Boxing the Compass 4
Broken Bones 205
Bubbles in Compass, Removing 58
Burns and Scalds 211

C

Canceling Licenses upon Request 238
Cardinal Points of Compass 3
Card of Deviations 97
Carrying Passengers at Night 241
in Various Classes of Airplanes 255
Causes of Variation of Compass 59
Central Time 23
Character, Age and Citizenship Qualifications 248
Charts and Maps 26
usually Mercator Projections of Water 31
Circle, Definition of 1
Diameter of 1
Great 17
Radius of 1
Small 17

PAGE
Circulatory System 208
Circumference of Circle, Division of 1
Cirro-Cumulus Clouds 193
Stratus Clouds 193
Cirrus Clouds 193
Civil Penalties 266
Classification of Mechanics 258
Pilots 248
Clockwise Graduation of Horizon 6
Clouds, Effects on Character of Day 195
Forms 192, 193, 194
Movements Forecast Weather 196
Relation to Weather 192
Storm Signals of the Sky 195
Cockpit and Cabin Construction 225
Comparing Great Circle and Rumb Tracks 41
Compass 47
Bearing 92
Bowl 50
Boxing 3
Cap 47
Cardinal Points of 3
Care and Installation 57
Compensation 76
Course 101
Deviation 59
Diagram or Rose 35
Earth Inductor 51
Errors 71
for Airplane 48
Graduations 50
Local Attraction 59
Meridian, Influence on Course 101
Mounting 58
Needle Dip 62
Points, Conversion New Compass Card 5
Radio 145
Readings on Turns 73
Rose, How Graduated 35
Sun 56
Variation 59
Compensating with Pelorus 88
Compensation for Large Deviations 83
of Compass 76
Components 112
Conformity in Maps 26
Constant Winds 171

PAGE

Continuous Duty as to Flying Condition 239
Contour Lines 33
Control System 224
Controller of Earth Inductor Compass 51
Conversion of Nautical to Statute Miles 274
  Time to Arc 22
  Table, Compass Points to Degrees 5
Correction of Courses 101
Correct Naming of Deviation Important 93
Course 14
  Angle 14
  Being Made Good 123
  Compass 101
  Correction of 101
  Correctors 34
  Error Table 273
    Use of 129
  How Affected by Drift 115
  Line or Track 34
  Magnetic 101
  Measuring and Correcting 139
  Setting with Inductor Compass 54
  True 101
  when Taking Off or Landing 263
Cross Country Work 136
Crossing Courses, Rule for 261
Cumulo-Nimbus 194
  Clouds 194
Cyclone Area 167
Cyclonic Storms 191

D

Daily and Periodic Inspection 240
Datum Level 33
Day Marks of Masts 266
Dead Ahead, Definition of 12
  Astern, Definition of 12
Declination of Needle 47
Department of Commerce Strip Maps 31
Deviations, Card of 97
  Clock 84
  Compass 59
  from Air Traffic Rules 266
  Quadrantal 72
  Table 92
Dew Point 168

PAGE

Diameter of Circle 1
Difference of Latitude 19
Dip of Compass Needle 63
Direction and Bearing Examples 10
Display and Surrender of License 238
of Identification Mark 218
Distance Finders 34
Measuring 36
Distress Landings 264
Signals 266
Dividers 34
Use of 36
Division of Circumference of Circle 1
Doldums at Equator 170
Dressing Burns 212
Drift Indicator, How Used 128
of Airplane 112
Problems, How to Solve 122
Triangle 119
Dropping Objects from Airplanes 263
Dumb Compass 87
Duration and Renewal of Pilots' Licenses 254
of Mechanics' License 258

E

Earth a Large Magnet 65
Axis of 17
Inductor Compass 51
Poles of 17
Eastern Time 23
Effect of Air Currents on Weather 168
Drift on Course 115
Emergency Splints 205
English Standard Time 23
Equator 17
Magnetic 62
Equidistance in Maps 26
Equipment and Instrument Requirements 229
Equivalance in Maps 26
Errors, Compass 71
Turning 72
Examination Questions for Transport Pilots 268-272
Examples for Converting Compass to True Course 106
Converting True to Compass Course 105
Finding Compass Course 131
Finding True Course 132
Latitude 19

PAGE
Speed, Course and Time 161
of Allowing for Drift 113
Clockwise Graduation 8
Course and Course Angle 15
Course Correction 155
Drift Triangle 119
Location Finding 159
Location of Position 24
Navigation in Cross Country Work 151
on Deviation 99
Exemption from Prescribed Physical Examination 251

F

Final Course 41
Fire Burns, Degrees of 211
First Aid 204
in Aviation Accidents 214
Flags for Storm Warning 201
Float Type Car 48
Flying Experience Requirements 249
Rules 260
Seriously Damaged Airplanes 242
Solo 255
Fog Signals 266
Foreign Air Commerce 242
Aircraft 219
Four Standard Time Zones in United States 23
Fractures, Compound 205
Simple 205
Freezing, or Exposure to Cold 212
Frostbites 213

G

Generator of Earth Inductor Compass 51
Geographic Meridian, Influence on Course 101
Geographical Map 31
Giving Way Duties 261
in Landing or Maneuvering 263
Glossary of Terms Used in Navigation and Meteorology . . 275-302
Gnomonic Projection Charts 42
Gradient, Barometric 168
Graduating Stabilizer in Degrees 126
of Horizon, Clockwise 6
Great Circle 17
and Rumb Tracks Compared 41

PAGE
Definitions 41
Sailings 38
Track 39
Track a Curve 40
Track, Finding 42
Greenwich Meridian 23
Grounds for Revocation or Suspension 239
Government Inspections 241

H

Heat Bumps 202
Height over Assembly of Persons 262
Height over Congested and Other Areas 262
Hemispheres 18
Hemorrhage, Checking 207
High Pressure Area 167
Horizon, Definition of 2
Division into Points 4
Graduation, Clockwise 6
Horse Latitudes 171
How to Use Pelorus 88
Humidity, Absolute 169
Relative 169
Hurricanes 191
Hydrodeik, Use of 169

I

Identification Mark Display 218
for Licensed Aircraft 243
for Special Classes of Aircraft 243
Identification Marks for Unlicensed Aircraft 244
Indicator, Turn and Bank 143
Induced Magnetism 64
Industrial Pilots 248
Initial Course 41
Inspection of Aircraft 231
Instrument Flying 142
Interval, Vertical 33
Iron, Hard and Soft 64
Isagonic Charts 62
Lines 62
Isobars, Definition of 174
Isoclinic Lines 63
Isodynamic Lines 63
Isotherms, Definition of 174

L

	PAGE
Landing Conditions	223
Latitude and Longitude Locates Position	24
Determination of	18
Horse	171
Middle	37
Parallels	18
Law of Air Traffic	260
Leeway	122
Level, Datum	33
License and Identification Plates	246
Licenses—Contents	236
Licensing Airplanes Not Constructed Under Approved Type Certificates	235
Licensing Law	217
of Aircraft	217
Airships and Balloons	238
Approved Type Airplanes	234
Mechanics, Law of	258
Pilots	246
Special Classes of Airplanes	236
Lights, Airplane	264
Airship	264
Angular Limits	264
Balloon	264
When Stationary	265
Limited Commercial Pilots	247
Lines, Contour	33
of Bearing	34
Bearing on Polyconic Charts	28
No Variation	60
Squalls	190
Load Factor Requirements	221
Local Attraction	74
Compass	59
Lodestone	45
Logs and Navigation Reports	242
Log Records of Engine Tests	226
Longitude, Definition of	20
Measurement in Degrees	21
in Time Units	21
Reckoning	20
Long Trips, How to Make	38
Low Barometer over Poles	170
Pressure Area	167
Lubber Line	48

M

PAGE

Magnetic Attraction 46
Axis 45
Course 101
Equator 62
Meridian 47
Meridian, Influence on Course 101
Poles 45
Poles of Airplane 67
Storms 74
Magnetism 45
by Induction 67
in Airplane Fuselage 67
Retentive 67
Subpermanent 67
Magnets Neutral Zone 45
Manufacturer's Identification Data 230
Maps and Charts 26
for Aerial Navigation 31
Physical and Geographical 31
Post Office Location 32
Railroad Location 136
Standard State 32
Strip 31
Topographical 33
usually Polyconic Projection of Land 31
Marine Charts 33
Marking of Aircraft, Law of 243
Marks on Airplanes 245
Airships 245
Balloons 245
Maximum Separation 42
Marking of Airplanes 238
Solo Flying 255
Measuring and Correcting Courses 139
Mechanics, Classification of 258
License, Duration and Renewal 258
Licensing 258
Qualifications and Examination 258
Mercator Projections 28
Best for Navigation 30
How Obtained 29
Mercurial Barometer 163
Meridians 18
Meridional Parts 30
Meteorological Equipment, Minimum 199

PAGE
Method of Take-off and Landing 263
Middle Latitude 37
Mile, Nautical 19
Miles, Conversion of Nautical to Statute 274
Moisture in Air 168
Monsoons, Reversal of 179
Mountain Time 23
Mounting for Compass 58

N

Natural Magnets 45
Nautical Mile 19
Navigation over Long Distances 39
Neutral Zone of Magnets 45
New Compass Card, Conversion Table 5
Newton's Laws of Motion 111
Nimbus Clouds 194
Northern Hemisphere 18
North Pole 17
Seeking Pole 45
Notes on Weather 180

O

Operation of Earth Inductor Compass 53
Radio Compass 146
Other Marks and Symbols 246
Overtaking, Definition of 261

P

Pacific or Western Time 23
Parallel Ruler 34
Use of 36
Parts, Meridional 30
of Mercurial Barometer 165
Pelorus for Compass Work 91
Use in Measuring Drift Angle 123
Use of 87
Penalty Proceedings 266
Violation of Air Traffic 260
Performance Requirements 228
Periodic Winds 172
Personal Possession of Mechanics' Licenses 259
Pilots' Licenses 254
Perturbations 74

PAGE
Physical Maps 31
Pilots, Classification of 248
Examinations and Tests 251
Flight Records 255
Industrial 248
Licensing of 248
Limited Commercial 247
Night Flying Qualifications 255
Physical Qualifications 249
Private 248
Privileges and Restrictions of 248
Transport 247
Place of Examination 253
Places and Dimensions of Marks 245
Planning Routes 137
Points, Cardinal 3
Polarity, Magnetic 45
Poles of Magnets 45
the Earth 17
Polyconic Projections 28
Port Bearing Points 14
Positions by Latitude and Longitude 24
Post Office Location Maps 32
Power Plant Installation 227
Requirements 225
Presumption of Overtaking 262
Prime or Zero Meridian 18
Private Pilots 248
Privileges and Restrictions of Licensed Pilots 248
Projections, Mercator 28
Polyconic 28
Propellers 228
Protractor, Use of 1, 34

Q

Quadrantal Deviation 72, 77
Questions for Review 268

R

Radio Beacon 148
Compass 145
Direction Finding 145
Radius of Circle 1
Railroad Location Map 136
Rainbows, Cause of 195

PAGE

Rand McNally State Air Trails 32
Reckoning Latitude 19
Records, Flights of Pilots 255
Rectilinear Motion 111
Registration, Meaning of 220
Relative Bearings 12
  Humidity 169
Relicensing of Aircraft 238
Renewal of Mechanic's License 258
Repairs after Accident Reports 242
Repulsion, Magnetic 46
Requisites for Licensing and Registration 219
Resultant 112
Retentive Magnetism 67
Reversal of Monsoons 179
Reverse Graduations 48
Revocation and Suspension of Licenses—Law 238
Right over Ground Planes 263
  Side Traffic 260
Rose or Compass Diagram 35
Routes, Planning 137
Rule for Converting Compass to True Course 106
    True to Compass Course 102
  Naming Deviation 93
  Time to Arc Conversion 22
Rumb Line 30

S

Sale of Licensed Aircraft 236
Saturation Point of Air 168
Savings Clause 267
Scales, Statute and Nautical 34
Seaplane Floats and Boat Hulls 224
  on Water 263
  Piloting 255
Semicircle Deviation 77
Signals, Airplane 266
  Distress 266
  in Fog 266
  When Compelled to Land 266
Sky at Sunset Indicates Weather 196
Small Circle 17
Solo Flights With Passenger Planes 241
  Flying 255
Southern Hemisphere 18
South Pole 17

PAGE

Seeking Pole 45
Speed 111
and Drift Indicator, Pioneer 126
Splints, Emergency 205
Sprains and Dislocations 214
Standard State Map 32
Starboard Bearing Points 13
State Air Trails, Maps of 32
Statute Miles to Nautical Miles, Conversion 274
Storm Areas, Point of Origination 173
Warning Flags 201
Strato-Cumulus Clouds 193
Stratus 195
Strip Maps 31
Study of Maps in Planning Courses 136
Subpermanent Magnetism 67
Suffocation and Shock 209
Suitable Flying Altitude 141
Sun Compass 56
Supplies and Equipment for Flight over Water 241
Suspension or Revocation of Mechanic's Licenses 259
Pilot's Licenses 256
Swinging Ship 84

T

Table of Barometer Readings and Weather Indicated 182
Tail Surfaces and Ailerons 223
Take-off and Landing Rules 263
Terms Used in Navigation and Meteorology 275-302
Thermometers, Wet and Dry Bulb 169
Thunderstorms 188
Time, Standard 23
Table, Use of 140
to Arc Conversion 22
Topographical Maps 33
Tornadoes 192
Tourniquet, How to Make 207
Trade Winds 172
Transport Pilots 247
Transporting Explosives by Airplane 263
Travel Rate of Storm Areas 174
True Course 101
Meridian 47
Turn and Bank Indicator 143
Turning Error 72
Turns, Effect on Compass Readings 73
Typical Time Table 140

U

PAGE
United States Standard Time Zones 23
Unlawful Acts, Air Traffic 260
Upper Air Wind Deviation Tables 187, 189
Atmosphere 183
Use of Drift Indicator 128
Induction Compass 55
Parallel Ruler 36
Using Radio Compass 146

V

Variable Winds 172
Variation and Deviation Differ 14
Easterly or Westerly 60
of Compass 59
Needle 47
Velocity 111
Vertex 42
Vertical Interval 33

W

Weather at High Altitudes 201
Indications for Barometer Readings 182
Jingles 198
Maps 174
Notes on 180
Observations 199
Signs 197
Wet and Dry Bulb Thermometers 169
Winds, Constant 171
Periodic 172
Trade 172
Variable 172

Z

Zero Meridian 18

CATALOGUE

No. 29

Of the Latest and Best

Practical and Mechanical Books

Including Aviation and
Automobile Books

PRACTICAL BOOKS FOR PRACTICAL MEN

Each Book in this Catalogue is written by an Expert and is written so you can understand it, and it will be sent prepaid to any address on receipt of the price

PUBLISHED BY

THE NORMAN W. HENLEY PUBLISHING CO.

2 WEST 45th STREET NEW YORK, U. S. A.

Established 1890

INDEX

	PAGE
Abrasives and Abrasive Wheels	25
Accidents	24
Air Brakes	23, 24
Alloys and Aluminum	3
Aluminum and Alloys	3
Arithmetic	15, 27, 37
Automobile Books	3, 4, 5, 6
Automobile Charts	6, 7
Automobile Ignition Systems	7
Automobile Lighting	4
Automobile Repairing	4
Automobile Starting Systems	7
Automobile Trouble Charts	6, 7
Automobile Welding	3
Aviation	7, 8, 9
Bells, Electric	15
Boats	9, 27
Boiler Room Chart	9
Brazing	9
Cams	20
Carburetion Trouble Chart	6
Carburetors	5
Car Charts	10
Cement	13
Change Gear	20
Charts	6, 7, 9, 10
Chemistry	10
Clock and Watch Making	10
Coal	23
Combustion	23
Concrete	11, 12, 13
Concrete for Farm Use	12
Concrete for Shop Use	12
Cosmetics	29
Dictionary	13, 17
Diesel Engines	13
Dies	13
Drawing	14, 30
Drawing for Plumbers	30
Dry Cleaning	14
Dynamo Building	15
Electric Bells	15
Electric Dictionary	13, 17
Electric Switchboards	16
Electric Toy Making	16
Electric Wiring	15, 16, 18
Electricity	15, 16, 17, 18
Electroplating	18, 19
Engine, Aviation	8
E-T Air Brake	24
Ford Automobile	4
Ford Tractor	4
Ford Trouble Chart	6
Formulas and Recipes	34
Fuel	23
Gas Engines	19, 20
Gas Tractor	40
Gearing and Cams	20
Glossary Aviation Terms	9
Heating	38
High Frequency Apparatus	17
Horology	11
Horse-Power Chart	10
Hot Water Heating	38
House Wiring	15, 18
Hydraulics	21
Ice	21
Ignition Systems	7
Ignition Trouble Chart	7
India Rubber	36
Inventions	21
Kerosene Carburetors	5
Knots	22
Lathe Work	22
Link Motions	25
Liquid Air	23
Locomotive Boilers	23
Locomotive Breakdowns	24
Locomotive Engineering	23, 24, 25
Machinist Books	25, 26, 27
Manual Training	28
Marine Gasoline Engines	20
Mechanical Drawing	14
Mechanical Movements	26
Metallurgy	3
Metal Work	13
Mining	28
Model Making	27
Motor Boats	29
Motorcycles	7, 28
Motor Truck	5
Patents	21
Pattern Making	29
Perfumery	29
Perspective	14
Plumbing	30, 31
Questions on Heating	38
Radio	31, 32, 33
Railroad Accidents	24
Railroad Charts	10
Recipe Book	35
Refrigeration	21
Repairing Automobiles	4
Rope Work	22
Rubber	36
Rubber Stamps	36
Saw Filing	36
Saws, Management of	36
Screw Cutting	36
Ship Models	27, 28
Shop Practice	25, 26
Shop Tools	25
Sketching Paper	14
Slide Valve	25
Soap Making	35
Soldering	9
Splices and Rope Work	22
Steam Engineering	36, 37, 38
Steam Heating	38
Steel	39
Storage Batteries	18
Submarine Chart	10
Switchboards	16
Tanning	39
Tapers	22
Telegraphy, Wireless	31, 32
Thread-Cutting	26
Tinsmithing	39
Tool Making	25
Toy Making	16
Tractive Power Chart	10
Tractor, Gas	40
Vacuum Heating	38
Valve Setting	25
Ventilation	38
Watch Making	10
Walschaert Valve Gear	24
Welding	3, 40
Wireless Telegraphy	31, 32
Wiring	15, 16, 18
Wiring Diagrams	16

Any of these books promptly sent prepaid to any address in the world on receipt of price.

HOW TO REMIT.—By Postal Money Order, Express Money Order, Bank Draft, or Registered Letter.

ALLOYS AND ALUMINUM

METALS AND THEIR ALLOYS. By CHARLES VICKERS.

This work is intensely practical, and is indispensable to everyone interested in metals and their alloys. The owner, manager, metallurgist, chemist or the worker in the shop will find here information that heretofore has been so difficult to obtain. It deals with metals from their origin to their useful application, both individually and as parts of alloys, used where strength, ductility, toughness, durability, lightness, color, hardness, cheapness, conductivity or bearing properties are demanded. The chapters on the casting of copper, the making of manganese bronze, aluminum bronze, aluminum alloys, red brass, yellow brass, steam metals, bearing metals, babbitts, white metals, phosphor bronze, gun metals and nickel alloys are crowded with formulas, tested and tried, together with the physical properties of the alloys and their casting peculiarities. It is a treasure-house of information for the metal worker, a convenient reference for the trained technical man, and a source of inspiration for the engineer who must select alloys most suitable for his work. 800 (6x9) pages. 110 illustrations. Price **$7.50**

METALLURGY OF ALUMINUM AND ALUMINUM ALLOYS. By ROBERT J. ANDERSON.

This volume is a modern, authoritative treatise on the metallurgy of aluminum and its light alloys, and covers the subject fully from the mining of the ores to the fabrication and applications of the metal. While it has been written especially with a view to being practical, the more theoretical aspects of the subject have not been neglected. The origin, occurrence and distribution of aluminum ores and methods of mining are taken up in an early chapter, while the production of aluminum itself by modern electrolytic methods is also discussed. The uses and applications of the metal and its alloys are treated in detail. Considerable attention is given to the preparation of alloys for casting and working, and the most approved methods for preparing the principal alloys are taken up. The best methods of melting, together with descriptions of the principal types of furnaces, are given detailed treatment. The founding of aluminum alloys, including casting losses and defects, is discussed quite fully, and the information will be of great value to foundrymen in the successful production of castings. 900 pages (6x9). 295 illustrations. Price . . **$10.00**

AUTOMOBILES

THE AUTOMOBILIST'S POCKET COMPANION AND EXPENSE RECORD. By VICTOR W. PAGÉ.

This book is not only valuable as a convenient cost record, but contains much information of value to motorists. Includes a condensed digest of auto laws of all States, a lubrication schedule, hints for care of storage battery, and care of tires, location of road troubles, anti-freezing solutions, horse-power table, driving hints and many useful tables and recipes of interest to all motorists. Pocket size. Price **$1.00**

AUTOMOBILE WELDING WITH THE OXY-ACETYLENE FLAME. By M. KEITH DUNHAM.

Explains in a simple manner apparatus to be used, its care, and how to construct necessary shop equipment. Proceeds then to the actual welding of all automobile parts, in a manner understandable by everyone. Gives principles never to be forgotten. This book is of utmost value, since the perplexing problems arising when metal is heated to a melting point are fully explained and the proper methods to overcome them shown. 167 pages. Fully illustrated. Price. **$1.50**

HINTS AND TIPS FOR AUTOMOBILISTS. By VICTOR W. PAGÉ.

The book is ideal for the busy man or woman who wants to know about car operation and upkeep because of the economies possible when an automobile is intelligently operated. It contains many money-saving hints and a brief simple exposition of location and remedy of roadside troubles apt to occur under ordinary operating conditions. Price . . . . . **75 cents**

AUTOMOBILE REPAIRING MADE EASY. By Victor W. Pagé, M.E.

A comprehensive, practical exposition of every phase of modern automobile repairing practice. Outlines every process incidental to motor car restoration. Gives plans for workshop construction, suggestions for equipment, power needed, machinery and tools necessary to carry on the business successfully. Tells how to overhaul and repair all parts of all automobiles. Everything is explained so simply that motorists and students can acquire a full working knowledge of automobile repairing. This work starts with the engine, then considers carburetion, ignition, cooling and lubrication systems. The clutch, change-speed gearing and transmission system are considered in detail. Contains instructions for repairing all types of axles, steering gears and other chassis parts. Many tables, short cuts in figuring and rules of practice are given for the mechanic. Explains fully valve and magneto timing, "tuning" engines, systematic location of trouble, repair of ball and roller bearings, shop kinks, first aid to injured and a multitude of subjects of interest to all in the garage and repair business.
This book contains special instructions on electric starting, lighting and ignition systems, tire repairing and rebuilding, autogenous welding, brazing and soldering, heat treatment of steel, latest timing practice, eight and twelve-cylinder motors, etc. 5¾x8. Cloth. 1060 pages, 1,000 illustrations, 11 folding plates. Price. **$3.00**

WHAT IS SAID OF THIS BOOK:

"'Automobile Repairing Made Easy' is the best book on the subject I have ever seen and the only book I ever saw that is of any value in a garage."—Fred Jeffrey, Martinsburg, Neb.
"I thank you for 'Automobile Repairing Made Easy.' I do not think it could be excelled."—S. W. Gisriel, Director of Instruction, Y. M. C. A., Philadelphia, Pa.

AUTOMOBILE STARTING, LIGHTING AND IGNITION SYSTEMS. By Victor W. Pagé, M.E.

This practical volume has been written with special reference to the requirements of the non-technical reader desiring easily understood, explanatory matter, relating to all types of automobile ignition, starting and lighting systems. It can be understood by anyone, even without electrical knowledge, because elementary electrical principles are considered before any attempt is made to discuss features of the various systems. These basic principles are clearly stated and illustrated with simple diagrams. *All the leading systems of starting, lighting and ignition have been described and illustrated with the co-operation of the experts employed by the manufacturers.* Wiring diagrams are shown in both technical and non-technical forms. All symbols are fully explained. It is a comprehensive review of modern starting and ignition system practice, and includes a complete exposition of storage battery construction, care and repair. All types of starting motors, generators, magnetos, and all ignition or lighting system units are fully explained. The systems of cars already in use as well as those that are to come are considered. *Every person in the automobile business needs this volume.* 5¼x7½. Cloth. 892 pages, 563 illustrations, over 325 Wiring Diagrams. Price . **$3.00**

HOW TO RUN AN AUTOMOBILE. By Victor W. Pagé.

This treatise gives concise instructions for starting and running all makes of gasoline automobiles, how to care for them, and gives distinctive features of control. Describes every step for shifting gears, controlling engine, etc. Among the chapters contained are: I. Automobile Parts and Their Functions. II. General Starting and Driving Instructions. III. Control Systems—Care of Automobiles. Thoroughly illustrated. 178 pages. 72 illustrations. Price **$1.00**

THE MODEL T FORD CAR, ITS CONSTRUCTION, OPERATION AND REPAIR, INCLUDING THE FORDSON FARM TRACTOR, F. A. LIGHTING AND STARTING SYSTEM, FORD MOTOR TRUCK. By Victor W. Pagé.

This is the most complete and practical instruction book ever published on the Ford car and Fordson tractor. All parts of the Ford Model T car and Fordson tractor are described and illustrated in a comprehensive manner. The construction is fully treated and operating principle made clear to everyone. Complete instructions for driving and repairing are given. To the New Revised Edition matter has been added on the Ford Truck and Tractor Conversion Sets and Genuine Fordson Tractor. All parts are described. All repair processes illustrated and fully explained. Written so all can understand—no theory, no guesswork. New revised and enlarged Edition just published. 187 illustrations, 455 pages, 2 large folding plates. Price . **$2.00**

THE MODERN GASOLINE AUTOMOBILE—ITS DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE. By Victor W. Pagé, M.E.

Just off the press—New 1928 Edition. This is the most complete automobile book ever issued. Covers every recent improvement in relation to the automobile. A complete illustrated description of the new Ford Model A Car is included. This is the most complete, practical and up-to-date treatise on automobiles and their component parts ever published. All phases of automobile construction, operation and maintenance are fully and completely described and in language anyone can understand. Every part of all types of automobiles from light cars to heavy motor trucks and road tractors is described in a thorough manner; not only the automobile but every item of its equipment, accessories, tools needed, supplies and spare parts necessary for its upkeep, are fully discussed. It fully considers the power plant and its auxiliaries, also chassis and body construction in minute detail. All latest developments, such as high speed motors, sleeve valve engines, straight eight engines, air cleaners, fuel filters, oil separators and rectifiers and numerous other developments are considered in detail. The latest ignition, carburetor and lubrication practice is outlined. New forms of change speed gears, and final power transmission systems, and all latest chassis improvements are shown and described, such as four-wheel brakes, air brake systems, balloon tires, hypoid gear drive, four-wheel drive, front-wheel drive, etc.

The large demand for the previous editions of this book, this being the sixth time the book has been completely revised and entirely reset, makes it possible to treat in detail all the latest improvements, including the new Model A Ford car.

This book has been the standard for many years, and is used in practically every automobile school, college and university as a textbook—and by the United States Army and Navy. 1000 new illustrations. 1150 (6x9) pages. Price $5.00

WHAT IS SAID OF THIS BOOK:

"It is the best book on the Automobile seen up to date."—J. H. Pile, Associate Editor *Automobile Trade Journal.*

"Every Automobile Owner has use for a book of this character."—*The Tradesman.*

"This book is superior to any treatise heretofore published on the subject."—*The Inventive Age.*

THE MODERN MOTOR TRUCK, ITS DESIGN, CONSTRUCTION, OPERATION AND REPAIR. By Victor W. Pagé.

Treats on all types of motor trucks and industrial tractors and trailers. It considers all types of trucks, gasoline and electric, and all varieties of truck bodies. This book is written in language everyone can understand and is not in any sense of the word a technical treatise. It is a practical volume that will make special appeal to the truck driver who seeks to better his position and to the mechanic charged with the repair and upkeep of trucks. The factory or business executive who wants to obtain a complete working knowledge of truck operation problems will find this book a reference work of great value. The truck salesman or automobile dealer will find that this work contains information that means money to them. All garage and service station men should have a copy of this book for reference because truck construction differs from passenger car design in many important respects. Anyone who reads this book is in touch with all the practical features that have been tested out in real service. Cloth (6x9) 962 pages, 750 illustrations. Price $4.00

GASOLINE AND KEROSENE CARBURETORS, CONSTRUCTION, INSTALLATION AND ADJUSTMENT. By Victor W. Pagé.

This is a simple, comprehensive, and authoritative treatise for practical men explaining all basic principles pertaining to carburetion, showing how liquid fuels are vaporized and turned into gas for operating all types of internal combustion engines intended to operate on vapors of gasoline, kerosene, benzol, and alcohol. All leading types of carburetors are described in detail, special attention being given to the forms devised to use the cheaper fuels such as kerosene. Carburetion troubles, fuel system troubles, carburetor repairs and installation, electric primers and economizers, hot spot manifolds and all modern carburetor developments are considered in a thorough manner. Methods of adjusting all types of carburetors are fully discussed as well as suggestions for securing maximum fuel economy and obtaining highest engine power.

This book is invaluable to repairmen, students, and motorists, as it includes the most complete exposition on kerosene carburetors ever published. The drawings showing carburetor construction are made from accurate engineering designs and show all parts of late types of carburetors. 213 pages. 89 illustrations. . $2.00

AUTOMOBILE, AVIATION AND MOTORCYCLE CHARTS

AVIATION CHART—LOCATION OF AIRPLANE POWER PLANT TROUBLES MADE EASY. By Major Victor W. Pagé, A.S., S.C.U.S.R.

A large chart outlining all parts of a typical airplane power plant, showing the points where trouble is apt to occur and suggesting remedies for the common defects. Intended especially for aviators and aviation mechanics on school and field duty. This chart was published during the year 1917. Price . . . . . **30 cents**

AUTOMOBILE CHARTS

GASOLINE ENGINE TROUBLES MADE EASY—A CHART SHOWING SECTIONAL VIEW OF GASOLINE ENGINE. Compiled by Victor W. Pagé, M.E.

It shows clearly all parts of a typical six-cylinder gasoline engine of the four-cycle type. It outlines distinctly all parts liable to give trouble and also details the derangements apt to interfere with smooth engine operation.

Valuable to students, motorists, mechanics, repairmen, garagemen, automobile salesmen, chauffeurs, motorboat owners, motor-truck and tractor drivers, aviators, motorcyclists, and all others who have to do with gasoline power plants.

It simplifies location of all engine troubles, and while it will prove invaluable to the novice, it can be used to advantage by the more expert. It should be on the walls of every public and private garage, automobile repair shop, club house or school. It can be carried in the automobile or pocket with ease, and will insure against loss of time when engine trouble manifests itself.

This sectional view of engine is a complete review of all motor troubles. It is prepared by a practical motorist for all who motor. More information for the money than ever before offered. No details omitted. Size 25x38 inches. Price . . . **35 cents**

LOCATION OF CARBURETION TROUBLES MADE EASY. Compiled by Victor W. Pagé, M.E.

This chart shows all parts of a typical pressure feed fuel supply system and gives causes of trouble, how to locate defects and means of remedying them. Size 24x38 inches. Price . . . . . **35 cents**

LOCATION OF FORD ENGINE TROUBLES MADE EASY. Compiled by Victor W. Pagé, M.E.

This shows clear sectional views depicting all portions of the Ford power plant and auxiliary groups. It outlines clearly all parts of the engine, fuel supply system, ignition group and cooling system, that are apt to give trouble, detailing all derangements that are liable to make an engine lose power, start hard or work irregularly. This chart is valuable to students, owners, and drivers, as it simplifies location of all engine faults. Of great advantage as an instructor for the novice, it can be used equally well by the more expert as a work of reference and review. It can be carried in the toolbox or pocket with ease and will save its cost in labor eliminated the first time engine trouble manifests itself. Prepared with special reference to the average man's needs and is a practical review of all motor troubles because it is based on the actual experience of an automobile engineer-mechanic with the mechanism the chart describes. It enables the non-technical owner or operator of a Ford car to locate engine derangements by systematic search, guided by easily recognized symptoms instead of by guesswork. It makes the average owner independent of the roadside repair shop when touring. Must be seen to be appreciated. Size 25x38 inches. Printed on heavy bond paper. Price . . . . . **35 cents**

LUBRICATION OF THE MOTOR CAR CHASSIS. Compiled by Victor W. Pagé, M.E.

This chart presents the plan view of a typical six-cylinder chassis of standard design and all parts are clearly indicated that demand oil, also the frequency with which they must be lubricated and the kind of oil to use. A practical chart for all interested in motor-car maintenance. Size 24x38 inches. Price . . . . . **35 cents**

LOCATION OF IGNITION SYSTEM TROUBLES MADE EASY. Compiled by VICTOR W. PAGÉ, M.E.

In this diagram all parts of a typical double ignition system using battery and magneto current are shown, and suggestions are given for readily finding ignition troubles and eliminating them when found. Size 24x38 inches. Price . . . . . **35 cents**

LOCATION OF STARTING AND LIGHTING SYSTEM FAULTS. Compiled by VICTOR W. PAGÉ, M.E.

The most complete chart yet devised, showing all parts of the modern automobile starting, lighting and ignition systems, giving instructions for systematic location of all faults in wiring, lamps, motor or generator, switches and all other units. Invaluable to motorists, chauffeurs and repairmen. Size 24x38 inches. Price . **35 cents**

MOTORCYCLE TROUBLES MADE EASY. Compiled by VICTOR W. PAGÉ, M.E.

A chart showing sectional view of a single-cylinder gasoline engine. This chart simplifies location of all power-plant troubles. A single-cylinder motor is shown for simplicity. It outlines distinctly all parts liable to give trouble and also details the derangements apt to interfere with smooth engine operation. This chart will prove of value to all who have to do with the operation, repair or sale of motorcycles. No details omitted. Size 30x20 inches. Price . . . . . **35 cents**

AVIATION

TWO NEW AVIATION BOOKS

Just off the press. Give complete information on every phase of aeronautics. Learn to Fly by flying, but prepare yourself in the ground work by Home Study, for experience in the air. Valuable books for reference. They will start you right.

MODERN AIRCRAFT, DESIGN-CONSTRUCTION-OPERATION AND REPAIR. By MAJOR VICTOR PAGÉ.

A book for all students of Aircraft. Just off the press. This book of 855 pages is the most complete work ever issued on Aviation. It is written in simple language for the Practical Man. It shows just how any airplane flies and is controlled, outlines and describes all important parts of the plane and just what they do and how they are used. Covers the commercial possibilities of aircraft types, outlines their spheres of usefulness and considers the cost of flying. The equipment of airports, airways and landing fields is touched upon and a complete and easily understood explanation of all branches of aerodynamics as well as a complete glossary of terms used in aeronautics are included. This booklet includes a description of the Ryan NYP monoplane flown from New York to Paris by Colonel Charles Lindbergh and the Wright-Bellanca monoplane flown by Clarence Chamberlain from New York to Berlin. It also describes fully the Fokker tri-motored monoplane used by Commander Byrd in his Polar and trans-oceanic flights. The Wright air-cooled motor and the navigating instruments that made these Epochal Flights possible are fully described.

Adopted as an Instruction Book in fifty aviation schools and colleges. 855 pages. Over 400 engravings. Price **$5.00**

WHAT IS SAID OF THIS BOOK

"Your new book, '*Modern Aircraft*' is a wonder. Very complete and up-to-the-minute. Highly interesting and a valuable contribution to the field of aviation. I feel that the author and publisher both have done fully 100 per cent. justice to this splendid book which really should be in the hands of every person interested in the progress of Modern Aircraft." (Signed) FRED W. DOBE,
1951 Lawrence Ave., Chicago, Ill.

EVERYBODY'S AVIATION GUIDE. By VICTOR W. PAGÉ.

A Popular Book at a Popular Price. This book, written in the form of a series of lessons or instructions, starts the reader at the beginning of the subject, outlines the elementary aerodynamical rules for the various forms of flying machines, describes typical conventional and unconventional forms of heavier-than-air and lighter-than-air craft, the functions of the various parts of an airplane, and covers briefly the various types of airplane power plants in both air and water-cooled forms. It outlines fully all types of land and sea flying machines, their control systems and the methods of flying. These are all fully illustrated.

While piloting an airplane can be learned only by actual practice, this book will give the reader the various steps in airplane control and will serve as a very valuable introduction to the entire subject of flying for the non-technical person who wishes to be able to fly an airplane just as he now operates an automobile for business or pleasure. 247 pages, 140 illustrations, 600 questions and answers on aviation. Price. **$2.00**

AVIATION BOOKS AT SPECIAL PRICES

As very large editions of books below were printed when published, and in order to reduce our stock we are offering these books at reduced prices.

Although these books were published a few years ago, they contain much information of value at the present time, and in order that those interested in aviation may avail themselves of these volumes we are now offering them at reduced prices to clear out the editions.

The principles of operation described in these books apply just as well to the latest types of airplanes and airships and their engines which have changed only in minor details from the forms illustrated, and they are just as valuable to the reader today. The beginner or student will get much information at low cost from the following books.

A B C OF AVIATION. By MAJOR VICTOR W. PAGÉ.

This book describes the basic principles of aviation, tells how a balloon or dirigible is made and why it floats in the air. Describes how an airplane flies. It shows in detail the different parts of an airplane, what they are and what they do. Describes all types of airplanes and how they differ in construction; as well as detailing the advantages and disadvantages of different types of aircraft. It includes a complete dictionary of aviation terms and clear drawings of leading airplanes. The reader will find simple instructions for unpacking, setting up, and rigging airplanes. A full description of airplane control principles is given and methods of flying are discussed at length.

This book answers every question one can ask about modern aircraft, their construction and operation. A self-educator on aviation without an equal. 274 pages. 130 specially made illustrations with 7 plates. Price **$1.25**

AVIATION ENGINES—DESIGN; CONSTRUCTION; REPAIR. By MAJOR VICTOR W. PAGÉ, A.S., S.C.U.S.R.

This treatise, written by a recognized authority on all of the practical aspects of internal combustion engine construction, maintenance, and repair, fills the need as no other book does. The matter is logically arranged; all descriptive matter is simply expressed and copiously illustrated, so that anyone can understand airplane engine operation and repair even if without previous mechanical training. This work is invaluable for anyone desiring to become an aviator or aviation mechanic. Rotary types, such as the Gnome Monosoupape, and LeRhone, are fully explained, as well as the Vee and radial types. The subjects of carburetion, ignition, cooling, and lubrication also are covered in a thorough manner. The chapters on repair and maintenance are distinctive and found in no other book on this subject. Not a technical book, but a practical, easily understood work of reference for all interested in aeronautical science. 589 pages. 253 illustrations. Price, net . . . **$1.25**

APPLIED AERODYNAMICS. By G. P. Thompson.

This is a scientific and mathematical treatise that has a special appeal to the student and engineer who are seeking exact information on the aerodynamics of heavier-than-air craft and data on airplane design testing. In addition to a very full discussion of the qualities which determine the speed and rate of climb of an aeroplane and the method by which they can be calculated, special attention is paid to stability—a problem now fairly well understood, and to controllability—our knowledge of which is at present in a much more elementary state. Attention is directed to the numerous directions in which further information is required, especially in the form of full-scale experiments. 312 pages (7 x 10). Illustrated with over 142 Diagrams and Graphic Charts. Price $5.00

GLOSSARY OF AVIATION TERMS—ENGLISH-FRENCH; FRENCH-ENGLISH. By Major Victor W. Pagé, A.S., S.C.U.S.R., and Lieut. Paul Montariol, of the French Flying Corps.

A complete glossary of practically all terms used in aviation, having lists in both French and English with equivalents in either language. Price, . . 50 cents

BOAT BUILDING

MINIATURE BOAT BUILDING. By Albert C. Leitch.

Covering the construction of working models of racing sail and power boats by amateurs. A concise and complete treatise written in understandable language covering marine model making in general and the specific design and construction of numerous famous miniature racing sail and power boats. The boats illustrated and described have been developed from an engineering point of view rather than from a toy angle. In this book the authors have illustrated and described step by step, the best model making practice, from the selection of the raw material to the completed boats. Complete designs for steam power plants, including tubular boilers and blow torch for firing them. One, two and four cylinder engines are also fully described. 500 specially prepared engravings. 242 pages. Price $3.00

BRAZING AND SOLDERING

BRAZING AND SOLDERING. By James F. Hobart.

The only book that shows you just how to handle any job of brazing or soldering that comes along: it tells you what mixture to use, how to make a furnace if you need one. Full of valuable kinks. The fifth edition of this book has just been published, and to it much new matter and a large number of tested formulæ for all kinds of solders and fluxes have been added. Illustrated. . . . . 35 cents

SOLDERING AND BRAZING. By Raymond Francis Yates.

This treatise gives all the necessary "kinks" that will enable one to accomplish successful soldering. If a mechanic has not succeeded in his soldering, this book may tell him just what he needs to produce good work—something that he may heretofore have forgotten. Price . . . . . 75 cents

CHARTS

BOILER ROOM CHART. By Geo. L. Fowler.

A chart—size 14x28 inches—showing in isometric perspective the mechanisms belonging in a modern boiler room. The various parts are shown broken or removed, so that the internal construction is fully illustrated. Each part is given a reference number, and these, with the corresponding name, are given in a glossary printed at the sides. . . . . 35 cents

GONDOLA CAR CHART.

A chart showing the anatomy of a gondola car, having every part of the car numbered and its proper reference name given in a reference list. . . . . **35 cents**

PASSENGER CAR CHART.

A chart showing the anatomy of a passenger-car, having every part of the car numbered and its proper name given in a reference list. . . . . **35 cents**

STEEL HOPPER BOTTOM COAL CAR.

A chart showing the anatomy of a steel Hopper Bottom Coal Car, having every part of the car numbered and its proper name given in a reference list. . . . . **35 cents**

TRACTIVE POWER CHART.

A chart whereby you can find the tractive power or drawbar pull of any locomotive without making a figure. Shows what cylinders are equal, how driving wheels and steam pressure affect the power. What sized engine you need to exert a given drawbar pull or anything you desire in this line. . . . . **50 cents**

HORSE-POWER CHART

Shows the horse-power of any stationary engine without calculation. No matter what the cylinder diameter of stroke, the steam pressure of cut-off, the revolutions, or whether condensing or non-condensing, it's all there. Easy to use, accurate, and saves time and calculations. Especially useful to engineers and designers. **50 cents**

SUBMARINE CHART.

A cross-section view, showing clearly and distinctly all the interior of a Submarine of the latest type. You get more information from this chart, about the construction and operation of a Submarine, than in any other way. No details omitted—everything is accurate and to scale. All the machinery and devices fitted in a Submarine Boat are shown. . . . . **35 cents**

CHEMISTRY

HOW TO MAKE AND USE A SMALL CHEMICAL LABORATORY. By Raymond Francis Yates.

The treatise covers all of the essentials of elementary chemistry. The law of definite proportions, solutions, crystalloids, colloids, electrolysis, etc., are explained. The second part of the book is devoted to chemical and electro-chemical experiments. Only those experiments that will tend to broaden the reader's knowledge of chemistry in general have been chosen. Price . . . . . **75 cents**

CLOCK AND WATCHMAKING

CLOCKMAKING: PAST AND PRESENT. By C. F. C. Gordon.

With which is incorporated the more important portion of "Clocks, Watches, and Bells," by the late Lord Grimthorpe, relating to Turret Clocks and Gravity Escapements. By G. F. C. Gordon, M.A., A.M.I.C.E., Superintendent of Workshops of the Engineering Department of Cambridge University. A practical book of special interest to the Clockmaker, Repairer, Dealer and Collector, in which the author endeavors to cover topics which either have not been covered before, or which from his own experience require more attention than they have hitherto received. 240 pages. Fully illustrated by Diagrams and plates of Long Case, Bracket and other Clocks, Dials, Hands, etc. Price **$5.00**

CLOCK REPAIRING AND MAKING. By F. J. Garrard.

Practical Watchmaker. Author of "Watch Repairing, Cleaning and Adjusting." A practical handbook dealing with Tools, Materials, and Methods used in cleaning and repairing all kinds of English and Foreign Timepieces, Striking and Chimney Clocks, and the making of English Clocks. 168 pages. Fourth edition. Illustrated by 120 engravings. Price **$3.00**

ELECTRICAL HOROLOGY. By H. R. Langman and A. Ball.

180 pages profusely illustrated. A practical manual on the application of the principles and practices of electricity to horological instruments and machines for the measurement and transmission of time with an account of the earliest electrically-driven clock mechanism. 180 pages. Illustrated. Price **$3.00**

THE WATCHMAKER'S HANDBOOK. By Claudius Saunier.

Translated from the French by Cladius Saunier, and enlarged by Julien Tripplin, F.R.A.S., and Edward Rigg, M.A. A workshop companion for those engaged in watchmaking and the allied mechanical arts. As an encyclopedia for the practical watchmaker and repairer this work stands paramount. The chapter on practical receipts alone is a mine of information. Over 500 pages. New and revised edition. 14 folding plates. Price **$5.00**

WATCH REPAIRING AND MAKING. By F. J. Garrard.

Practical Watchmaker. Author of "Watch Repairing, Cleaning and Adjusting." Covers the Cleaning and Repairing of Watches. Treats on the materials and tools used. Shows how to alter and adjust all kinds of English and Foreign Watches, Repeaters, Chronographs and Marine Chronometers. 214 pages. Seventh edition. Illustrated by over 200 engravings. Price **$3.00**

CONCRETE

CONCRETE WORKERS' REFERENCE BOOKS. A SERIES OF POPULAR HANDBOOKS FOR CONCRETE USERS. Prepared by A. A. Houghton.

The author, in preparing this Series, has not only treated on the usual types of construction, but explains and illustrates molds and systems that are not patented, but which are equal in value and often superior to those restricted by patents. These molds are very easily and cheaply constructed and embody simplicity, rapidity of operation, and the most successful results in the molded concrete. Each of these books is fully illustrated, and the subjects are exhaustively treated in plain English.

CONCRETE WALL FORMS. By A. A. Houghton.

A new automatic wall clamp is illustrated with working drawings. Other types of wall forms, clamps, separators, etc., are also illustrated and explained. (No. 1 of Series) . . . . . **75 cents**

CONCRETE FLOORS AND SIDEWALKS. By A. A. Houghton.

The molds for molding squares, hexagonal and many other styles of mosaic floor and sidewalk blocks are fully illustrated and explained. (No. 2 of Series) . . **75 cents**

PRACTICAL CONCRETE SILO CONSTRUCTION. By A. A. Houghton.

Complete working drawings and specifications are given for several styles of concrete silos, with illustrations of molds for monolithic and block silos. The tables, data, and information presented in this book are of the utmost value in planning and constructing all forms of concrete silos. (No. 3 of Series) . . . . . **75 cents**

MOLDING CONCRETE CHIMNEYS, SLATE AND ROOF TILES. By A. A. Houghton.

The manufacture of all types of concrete slate and roof tile is fully treated. Valuable data on all forms of reinforced concrete roofs are contained within its pages. The construction of concrete chimneys by block and monolithic systems is fully illustrated and described. A number of ornamental designs of chimney construction with molds are shown in this valuable treatise. (No. 4 of Series.) . . . . . **75 cents**

MOLDING AND CURING ORNAMENTAL CONCRETE. By A. A. Houghton.

The proper proportions of cement and aggregates for various finishes, also the method of thoroughly mixing and placing in the molds, are fully treated. An exhaustive treatise on this subject that every concrete worker will find of daily use and value (No. 5 of Series.) . . . . . **75 cents**

CONCRETE MONUMENTS, MAUSOLEUMS AND BURIAL VAULTS. By A. A. HOUGHTON.

The molding of concrete monuments to imitate the most expensive cut stone is explained in this treatise, with working drawings of easily built molds. Cutting inscriptions and designs are also fully treated. (No. 6 of Series.) . . . **75 cents**

MOLDING CONCRETE BATHTUBS, AQUARIUMS AND NATATORIUMS. By A. A. HOUGHTON.

Simple molds and instruction are given for molding many styles of concrete bathtubs, swimming-pools, etc. These molds are easily built and permit rapid and successful work. (No. 7 of Series.) . . . . . **75 cents**

CONCRETE BRIDGES, CULVERTS AND SEWERS. By A. A. HOUGHTON.

A number of ornamental concrete bridges with illustrations of molds are given. A collapsible center or core for bridges, culverts and sewers is fully illustrated with detailed instructions for building. (No. 8 of Series.) . . . . . **75 cents**

CONSTRUCTING CONCRETE PORCHES. By A. A. HOUGHTON.

A number of designs with working drawings of molds are fully explained so anyone can easily construct different styles of ornamental concrete porches without the purchase of expensive molds. (No. 9 of Series.) . . . . . **75 cents**

MOLDING CONCRETE FOUNTAINS AND LAWN ORNAMENTS. By A. A. HOUGHTON.

The molding of a number of designs of lawn seats, curbing, hitching posts, pergolas, sun dials and other forms of ornamental concrete for the ornamentation of lawns and gardens, is fully illustrated and described. (No. 11 of Series) . . . . . **75 cents**

CONCRETE FOR THE FARM AND IN THE SHOP. BY H. COLIN CAMPBELL, C.E., E.M.

A new book illustrating and describing in plain, simple language many of the numerous applications of concrete within the range of the home worker. Among the subjects treated are:

Principles of reinforcing; methods of protecting concrete so as to insure proper hardening; home-made mixers; mixing by hand and machine; form construction, described and illustrated by drawings and photographs; construction of concrete walls and fences; concrete fence posts; concrete gate posts; corner posts; clothes line posts; grape arbor posts; tanks; troughs; cisterns; hog wallows; feeding floors and barnyard pavements; foundations; well curbs and platforms; indoor floors; sidewalks; steps; concrete hotbeds and cold frames; concrete slab roofs; walls for buildings; repairing leaks in tanks and cisterns, etc., etc. A number of convenient and practical tables for estimating quantities, and some practical examples, are also given. (5 x 7). 149 pages, 51 illustrations. Price **$1.00**

CONCRETE FROM SAND MOLDS. By A. A. HOUGHTON.

A Practical Work treating on a process which has heretofore been held as a trade secret by the few who possessed it, and which will successfully mold every and any class of ornamental concrete work. The process of molding concrete with sand molds is of the utmost practical value, possessing the manifold advantages of a low cost of molds, the ease and rapidity of operation, perfect details to all ornamental designs, density and increased strength of the concrete, perfect curing of the work without attention and the easy removal of the molds regardless of any undercutting the design may have. 192 pages. Fully illustrated. Price **$2.00**

ORNAMENTAL CONCRETE WITHOUT MOLDS. By A. A. HOUGHTON.

The process for making ornamental concrete without molds has long been held as a secret, and now, for the first time, this process is given to the public. The book reveals the secret and is the only book published which explains a simple, practical method whereby the concrete worker is enabled, by employing wood and metal templates of different designs, to mold or model in concrete any Cornice, Archivolt, Column, Pedestal, Base Cap, Urn or Pier in a monolithic form—right upon the job. These may be molded in units or blocks, and then built up to suit the specifications demanded. This work is fully illustrated, with detailed engravings. Price . **$2.00**

POPULAR HANDBOOK FOR CEMENT AND CONCRETE USERS. By MYRON H. LEWIS.

The author has brought together in this work all the salient matter of interest to the user of concrete and its many diversified products. The matter is presented in logical and systematic order, clearly written, fully illustrated and free from involved mathematics. Everything of value to the concrete user is given, including kinds of cement employed in construction, concrete architecture, inspection and testing, waterproofing, coloring and painting, rules, tables, working and cost data. The book comprises thirty-three chapters 430 pages, 126 illustrations. Price **$3.00**

DICTIONARIES

STANDARD ELECTRICAL DICTIONARY. By T. O'CONOR SLOANE.

An indispensable work to all interested in electrical science. Suitable alike for the student and professional. A practical handbook of reference containing definitions of about 5000 distinct words, terms and phrases. The definitions are terse and concise and include every term used in electrical science. Recently issued. An entirely new edition. Should be in the possession of all who desire to keep abreast with the progress of this branch of science. Complete, concise and convenient. 790 pages. 497 illustrations. New Revised and Enlarged Edition. Price **$5.00**

DIESEL ENGINE

DIESEL ENGINES: THEIR APPLICATION AND OPERATON—MARINE —LOCOMOTIVE—STATIONARY. By DAVID L. JONES.

This is the latest book on the subject of Diesel Engines written purely from a practical standpoint, in simple language, to enable the operator and the student to grasp the principles of this type of machine and to bring out the advantages of this form of prime mover in its various fields of operation.

It should be found upon the desk of every power station operating engineer and every student of mechanical engineering, as it contains data that is invaluable, and is the only American book containing an illustrated chapter on the application of the Diesel Engine to Railway Service. The importance of the Diesel Engine cannot be overestimated and the progressive engineer will find it his duty to extend his knowledge into the Diesel Engine field. Among the chapters are: The Diesel Engine—Elementary Thermodynamics—Elementary Principles—Comparative Efficiencies—Details of Construction—Spray Valves—Fuel Pumps, Governors, Fuel Systems—Valve Gears—Starting and Reversing Gears—Lubricating and Circulating Water Systems—Indicator Cards and Engine Testing—Operation of Diesel Engines—Representative Types of Engines—Representative Types of Engines continued—A 1000 Horse Power Submarine Diesel Engine—Diesel Engines for Railroad Service—Diesel Electric Drive for Ships—Properties of Lubricating and Fuel Oils—Marine Rules for Vessels Propelled by Diesel Oil Engines. 565 pages. 341 illustrations. Price. **$5.00**

DIES—METAL WORK

DIES: THEIR CONSTRUCTION AND USE FOR THE MODERN WORKING OF SHEET METALS. By J. V. WOODWORTH.

A most useful book, and one which should be in the hands of all engaged in the press-working of metals; treating on the Designing, Constructing, and Use of Tools, Fixtures and Devices, together with the manner in which they should be used in the Power Press, for the cheap and rapid production of the great variety of sheet-metal articles now in use. It is designed as a guide to the production of sheet-metal parts at the minimum of cost with the maximum of output. The hardening and tempering of Press tools and the classes of work which may be produced to the best advantage by the use of dies in the power press are fully treated. Its 546 illustrations show dies, press fixtures and sheet-metal working devices, the descriptions of which are so clear and practical that all metal-working mechanics will be able to understand how to design, construct and use them. 7th Edition. 426 pages, 546 illustrations. Price. . **$4.00**

DRY CLEANING

PRACTICAL DRY CLEANER, SCOURER AND GARMENT DYER. By WILLIAM T. BRANNT.

The sixth corrected edition of this work us just off the press. It is the most comprehensive and complete reference and text book for cleaners and dyers published and treats fully on cleaning plant design and construction; purification of benzine dry cleaning; spot and stain removal; wet cleaning, including the cleaning of Palm Beach suits and other summer fabrics; finishing cleaned fabrics; cleaning and dyeing furs, skins, rugs and mats; cleaning and dyeing feathers; cleaning, dyeing and blocking straw, felt and Panama hats; cleaning and dyeing rugs and carpets; bleaching and stripping garments; bleaching and dyeing straw and straw hats; cleaning and dyeing gloves; garment dyeing; analysis of textile fabrics; practical chemistry for the dry cleaner and garment dyer. 578 pages, 41 illustrations. Price **$3.00**

DRAWING—SKETCHING PAPER

LINEAR PERSPECTIVE SELF-TAUGHT. By HERMAN T. C. KRAUS.

This work gives the theory and practice of linear perspective, as used in architectural, engineering and mechanical drawings. Persons taking up the study of the subject by themselves will be able, by the use of the instruction given, to readily grasp the subject, and by reasonable practice become good perspective draftsmen. The arrangement of the book is good; the plate is on the left-hand, while the descriptive text follows on the opposite page, so as to be readily referred to. The drawings are on sufficiently large scale to show the work clearly and are plainly figured. There is included a self-explanatory chart which gives all information necessary for the thorough understanding of perspective. This chart alone is worth many times over the price of the book. 2d Revised and enlarged Edition. **$3.00**

PRACTICAL PERSPECTIVE. By RICHARDS and COLVIN.

Shows just how to make all kinds of mechanical drawings in the only practical perspective isometric. Makes everything plain so that any mechanic can understand a sketch or drawing in this way. Saves time in the drawing room, and mistakes in the shops. Contains practical examples of various classes of work. 5th Edition. **$1.00**

SELF-TAUGHT MECHANICAL DRAWING AND ELEMENTARY MACHINE DESIGN. By F. L. SYLVESTER, M.E., Draftsman, with additions by ERIK OBERG, associate editor of "Machinery."

This is a practical treatise on Mechanical Drawing and Machine Design, comprising the first principles of geometric and mechanical drawing, workshop mathematics, mechanics, strength of materials and the calculations and design of machine details. The author's aim has been to adapt this treatise to the requirements of the practical mechanic and young draftsman and to present the matter in as clear and concise a manner as possible. To meet the demands of this class of students, practically all the important elements of machine design have been dealt with, and in addition algebraic formulas have been explained, and the elements of trigonometry treated in the manner best suited to the needs of the practical man. The book is divided into 22 chapters, and in arranging the material, mechanical drawing, pure and simple, has been taken up first, as a thorough understanding of the principles of representing objects facilitates the further study of mechanical subjects. This is followed by the mathematics necessary for the solution of the problems in machine design which are presented later, and a practical introduction to theoretical mechanics and the strength of materials. The various elements entering into machine design, such as cams, gears, sprocket-wheels, cone pulleys, bolts, screws, couplings, clutches, shafting and fly-wheels, have been treated in such a way as to make possible the use of the work as a text-book for a continuous course of study. 345 pages, 237 engravings. Price **$2.50**

A NEW SKETCHING PAPER.

A new specially ruled paper to enable you to make sketches or drawings in isometric perspective without any figuring or fussing. It is being used for shop details as well as for assembly drawings, as it makes one sketch do the work of three, and no workman can help seeing just what is wanted. Pads of 40 sheets, 6x9 inches, **40 cents.** Pads of 40 sheets, 9x12 inches, **75 cents**; 40 sheets, 12x18, Price **$1.50**

ELECTRICITY

ARITHMETIC OF ELECTRICITY. By Prof. T. O'Conor Sloane.

A practical treatise on electrical calculations of all kinds reduced to a series of rules, all of the simplest forms, and involving only ordinary arithmetic; each rule illustrated by one or more practical problems, with detailed solution of each one. This book is classed among the most useful works published on the science of electricity, covering as it does the mathematics of electricity in a manner that will attract the attention of those who are not familiar with algebraical formulas. 22nd Edition. 196 pages. Price **$1.50**

COMMUTATOR CONSTRUCTION. By Wm. Baxter, Jr.

The business end of any dynamo or motor of the direct current type is the commutator. This book goes into the designing, building, and maintenance of commutators, shows how to locate troubles and how to remedy them; everyone who fusses with dynamos needs this. 5th Edition . . . . . **35 cents**

DYNAMO BUILDING FOR AMATEURS, OR HOW TO CONSTRUCT A FIFTY-WATT DYNAMO. By Arthur J. Weed, Member of N. Y. Electrical Society.

A practical treatise showing in detail the construction of a small dynamo or motor, the entire machine work of which can be done on a small foot lathe. Dimensioned working drawings are given for each piece of machine work, and each operation is clearly described. This machine, when used as a dynamo, has an output of fifty watts; when used as a motor it will drive a small drill press or lathe. It can be used to drive a sewing machine on any and all ordinary work. The book is illustrated with more than sixty original engravings showing the actual construction of the different parts. Among the contents are chapters on: 1. Fifty-Watt Dynamo. 2. Side Bearing Rods. 3. Field Punching. 4. Bearings. 5. Commutator. 6. Pulley. 7. Brush Holders. 8. Connection Board. 9. Armature Shaft. 10. Armature. 11. Armature Winding. 12. Field Winding. 13. Connecting and Starting. Price, cloth, **$1.00**

ELECTRIC BELLS. By M. B. Sleeper.

A complete treatise for the practical worker in installing, operating, and testing bell circuits, burglar alarms, thermostats, and other apparatus used with electric bells. Both the electrician and the experimenter will find in this book new material which is essential in their work. Tools, bells, batteries, unusual circuits, burglar alarms, annunciators, systems, thermostats, circuit breakers, time alarms, and other apparatus used in bell circuits are described from the standpoints of their application, construction, and repair. The detailed instructions for building the apparatus will appeal to the experimenter particularly. The practical worker will find the chapters on Wiring Calculation of Wire Sizes and Magnet Windings, Upkeep of Systems and the Location of Faults of the greatest value in their work. 124 pages. Fully illustrated. Price . . . . . **75 cents**

HOUSE WIRING. By Thomas W. Poppe.

This work describes and illustrates the actual installation of Electric Light Wiring, the manner in which the work should be done, and the method of doing it. The book can be conveniently carried in the pocket. It is intended for the Electrician, Helps, and Apprentice. It solves all Wiring Problems and contains nothing that conflicts with the rulings of the National Board of Fire Underwriters. It gives just the information essential to the Successful Wiring of a Building. Among the subjects treated are Locating the Meter. Panel Boards. Switches. Plug Receptacles. Brackets. Ceiling Fixtures. The Meter Connections. The Feed Wires. The Steel Armored Cable System. The Flexible Steel Conduit System. The Ridig Conduit System. A digest of the National Board of Fire Underwriters' rules relating to metallic wiring systems. Various switching arrangements explained and diagrammed. The easiest method or testing the Three- and Four-way circuits explained. The grounding of all metallic wiring systems and the reason for doing so shown and explained. The insulation of the metal parts of lamp fixtures and the reason for the same described and illustrated. 208 pages. 5th Edition, revised and enlarged. 160 illustrations. Flexible cloth. Price **$1.00**

ELECTRICIANS' HANDY BOOK. By Prof. T. O'Conor Sloane.

This work is intended for the practical electrician who has to make things go. The entire field of electricity is covered within its pages. Among some of the subjects treated are: The Theory of the Electric Current and Circuit, Electro-Chemistry, Primary Batteries, Storage Batteries, Generation and Utilization of Electric Powers, Alternating Current, Armature Winding, Dynamos and Motors, Motor Generators, Operation of the Central Station Switchboards, Safety Appliances, Distribution of Electric Light and Power, Street Mains, Transformers, Arc and Incandescent Lighting, Electric Measurements, Photometry, Electric Railways, Telephony, Bell-Wiring, Electric-Plating, Electric Heating, Wireless Telegraphy, etc. It contains no useless theory; everything is to the point. It teaches you just what you want to know about electricity. It is the standard work published on the subject. Forty-six chapters, 600 engravings. New 5th Edition, Revised and Enlarged. Price **$4.00**

ELECTRIC TOY MAKING, DYNAMO BUILDING, AND ELECTRIC MOTOR CONSTRUCTION. By Prof. T. O'Conor Sloane.

This work treats of the making at home of electrical toys, electrical apparatus, motors, dynamos and instruments in general, and is designed to bring within the reach of young and old the manufacture of genuine and useful electrical appliances. The work is especially designed for amateurs and young folks.

Thousands of our young people are daily experimenting, and busily engaged in making electrical toys and apparatus of various kinds. The present work is just what is wanted to give the much needed information in a plain, practical manner, with illustrations to make easy the carrying out of the work. 21st Edition. 254 pages, 118 illustrations. Price **$1.50**

ELECTRIC WIRING, DIAGRAMS AND SWITCHBOARDS. By Newton Harrison.

A thoroughly practical treatise covering the subject of Electric Wiring in all its branches, including explanations and diagrams which are thoroughly explicit and greatly simplify the subject. Practical, every-day problems in wiring are presented and the method of obtaining intelligent results clearly shown. Only arithmetic is used. Ohm's law is given a simple explanation with reference to wiring for direct and alternating currents. The fundamental principle of drop of potential in circuits is shown with its various applications. The simple circuit is developed with the position of mains, feeders and branches; their treatment as a part of a wiring plan and their employment in house wiring clearly illustrated. Some simple facts about testing are included in connection with the wiring. Molding and conduit work are given careful consideration; and switchboards are systematically treated, built up and illustrated, showing the purpose they serve, for connection with the circuits, and to shunt and compound wound machines. The simple principles of switchboard construction, the development of the switchboard, the connections of the various instruments, including the lightning arrester, are also plainly set forth.

Alternating current wiring is treated, with explanations of the power factor, conditions calling for various sizes of wire, and a simple way of obtaining the sizes for single-phase, two-phase and three-phase circuits. This is the only complete work issued showing and telling you what you should know about direct and alternating current wiring. It is a ready reference. The work is free from advanced technicalities and mathematics, arithmetic being used throughout. It is in every respect a handy, well-written, instructive, comprehensive volume on wiring for the wireman, foreman, contractor, or electrician. 3rd edition, revised and enlarged. 315 pages; 137 illustrations. Price **$2.50**

EXPERIMENTAL HIGH FREQUENCY APPARATUS — HOW TO MAKE AND USE IT. By Thomas Stanley Curtis.

This book tells you how to build simple high frequency coils for experimental purpose in the home, school laboratory, or on the small lecture platform. The book is really a supplement to the same author's "High Frequency Apparatus." The experimental side only is covered in this volume, which is intended for those who want to build small coils giving up to an eighteen-inch spark. The book contains valuable information for the physics or the manual training teacher who is on the lookout for interesting projects for his boys to build or experiment with. The apparatus is simple, cheap and perfectly safe, and with it some truly startling experiments may be performed. Among the contents are: Induction Coil Outfits Operated on Battery Current. Kicking Coil Apparatus. One-Half Kilowatt Transformer Outfit. Parts and Materials, etc., etc. 69 pages. Illustrated. Price . . . . . **50 cents**

ELECTRICITY SIMPLIFIED. By Prof. T. O'Conor Sloane.

The object of "Electricity Simplified" is to make the subject as plain as possible and to show what the modern conception of electricity is; to show how two plates of different metal, immersed in acid, can send a message around the globe; to explain how a bundle of copper wire rotated by a steam engine can be the agent in lighting our streets, to tell what the volt, ohm and ampere are, and what high and low tension mean; and to answer the questions that perpetually arise in the mind in this age of electricity. 15th Revised Edition. 218 pages. Illustrated. Price . . **$1.50**

EVERYBODY'S ELECTRICAL HANDBOOK. By Edward J. Volk, Practical Electrician.

Anyone with the aid of this book can do almost any of the small electrical jobs about the home. Everything is written in plain language. It tells how to start, what to use, and every move until this work is completed. In repairing electrical devices it tells where to locate the trouble and how to repair it. You will find this book different from any other book you have ever read. Should be in every home. Second edition. Pocket size. 135 pages. 78 Illustrations. Price **$1.00**

HIGH FREQUENCY APPARATUS, ITS CONSTRUCTION AND PRACTICAL APPLICATION. By Thomas Stanley Curtis.

The most comprehensive and thorough work on this interesting subject ever produced. The book is essentially practical in its treatment and it constitutes an accurate record of the researches of its author over a period of several years, during which time dozens of coils were built and experimented with. The work has been divided into six basic parts. The first two chapters tell the uninitiated reader what the high frequency current is, what it is used for, and how it is produced. The second section, comprising four chapters, describes in detail the principles of the transformer, condenser, spark gap, and oscillation transformer, and covers the main points in the design and construction of these devices as applied to the work in hand. The third section covers the construction of small high frequency outfits designed for experimental work in the home laboratory or in the classroom. The fourth section is devoted to electro-therapeutic and X-Ray apparatus. The fifth describes apparatus for the cultivation of plants and vegetables. The sixth section is devoted to a comprehensive discussion of apparatus of large size for use upon the stage in spectacular productions. The closing chapter, giving the current prices of the parts and materials required for the construction of the apparatus described, is included with a view to expediting the purchase of the necessary goods. The Second Edition includes much new matter along the line of home-made therapeutic outfits for physicians' use. The matter on electro plant culture has also been elaborated upon. Second Revised and Enlarged Edition. 266 pages. New second edition. Fully illustrated. Price . **$3.00**

STANDARD ELECTRICAL DICTIONARY. By T. O'Conor Sloane.

An indispensable work to all interested in electrical science. Suitable alike for the student and professional. A practical handbook of reference containing definitions of about 5,000 distinct words, terms and phrases. The definitions are terse and concise and include every term used in electrical science. Recently issued. An entirely new edition. Should be in the possession of all who desire to keep abreast with the progress of this branch of science. In its arrangement and typography the book is very convenient. The word or term defined is printed in black-faced type which readily catches the eye, while the body of the page is in smaller but distinct type. The definitions are well worded, and so as to be understood by the non-technical reader. The general plan seems to be to give an exact, concise definition, and then amplify and explain in a more popular way. Synonyms are also given, and references to other words and phrases are made. A very complete and accurate index of fifty pages is at the end of the volume; and as this index contains all synonyms, and as all phrases are indexed in every reasonable combination of words, reference to the proper place in the body of the book is readily made. It is difficult to decide how far a book of this character is to keep the dictionary form, and to what extent it may assume the encyclopedia form. For some purposes, concise, exactly worded definitions are needed; for other purposes, more extended descriptions are required. This book seeks to satisfy both demands, and does it with considerable success. Complete, concise and convenient. 790 pages. 497 illustrations. New Revised and Enlarged Edition. Price **$5.00**

HOW TO BECOME A SUCCESSFUL ELECTRICIAN. By Prof. T. O'Conor Sloane.

Every young man who wishes to become a successful electrician should read this book. It tells in simple language the surest and easiest way to become a successful electrician. The studies to be followed, methods of work, field of operation and the requirement, of the successful electrician are pointed out and fully explained. Every young engineer will find this an excellent stepping stone to more advanced works on electricity which he must master before success can be attained. Many young men become discouraged at the very outstart by attempting to read and study books that are far beyond their comprehension. This book serves as the connecting link between the rudiments taught in the public schools and the real study of electricity. It is interesting from cover to cover. 19th Revised Edition, just issued. 205 pages. Illustrated. Price **$1.50**

STORAGE BATTERIES SIMPLIFIED. By Victor W. Pagé, M.S.A.E.

A complete treatise on storage battery operating principles, repairs and applications. The greatly increasing application of storage batteries in modern engineering and mechanical work has created a demand for a book that will consider this subject completely and exclusively. This is the most thorough and authoritative treatise ever published on this subject. It is written in easily understandable, non-technical language so that anyone may grasp the basic principles of storage battery action as well as their practical industrial applications. All electric and gasoline automobiles use storage batteries. Every automobile repairman, dealer or salesman should have a good knowledge of maintenance and repair of these important elements of the motor car mechanism. This book not only tells how to charge, care for and rebuild storage batteries but also outlines all the industrial uses. Learn how they run street cars, locomotives and factory trucks. Get an understanding of the important functions they perform in submarine boats, isolated lighting plants, railway switch and signal systems, marine applications, etc. This book tells how they are used in central station standby service, for starting automobile motors and in ignition systems. Every practical use of the modern storage battery is outlined in this treatise. 258 pages. Fully illustrated. Price **$2.00**

WIRING A HOUSE. By Herbert Pratt.

Shows a house already built; tells how to start about wiring it; where to begin; what wire to use; how to run it according to insurance rules; in fact, just the information you need. Directions apply equally to a shop. We have just issued an enlarged edition of this popular work, which has been brought up to date. The same treatment of the subject which is distinguished by simplicity, combined with a correct presentation of the subject, from the standpoint of compliance with the Underwriter's Code, and which characterized the earlier editions of the book is adhered to. The wiring as given is based on the twenty-five watt tungsten filament lamp, now as much the standard as was the old sixteen candle carbon filament lamp of former days. The modern tungsten filament gas-filled lamp of today has changed the whole phase of electric wiring of the home and factory, and this book not only tells of the wiring for an installation, but also gives some very up-to-date suggestions on the subjects of selection of electroliers and fittings, location of lamps and base sockets with many practical hints for the location of lamps and plug sockets to get the best results. Seventh edition which has been entirely revised, and very much enlarged. Price . . **50 cents**

ELECTROPLATING

THE MODERN ELECTROPLATER. By Kenneth M. Coggeshall.

This is one of the most complete and practical books on electroplating and allied processes that has been published as a text for the student or professional plater. It is written in simple language and explains all details of electroplating in a concise yet complete manner. It starts at the beginning and gives an elementary outline of electricity and chemistry as relates to plating, then considers shop layout and equipment and gives all the necessary information to do reliable and profitable electroplating in a modern commercial manner. Full instructions are given for the preparation and finishing of the work and formulae and complete directions are included for making all kinds of plating solutions, many of these having been trade secrets until published in this instruction manual. Anyone interested in practical plating and metal finishing will find this book a valuable guide and complete manual of the art. Cloth. 142 illustrations. 276 pages. Price **$3.00**

ELECTRO-DEPOSITION OF METALS. By Dr. George Langbein and William T. Brannt.

The ninth corrected edition of this work contains everything anyone wants to know about the plating and finishing of metals, and is practically an encyclopedia of the industry. It is written in plain language with special reference to the needs of the practical plater and metal finisher, and gives hundreds of tested formulas for solutions many of which have heretofore been considered trade secrets. It is the master treatise on electro-plating, galvanizing, metal coloring, lacquering and electrotyping, and covers every detail of the present advanced state of the art in its everyday applications. The interest of most readers will doubtless center in the main division of the volume—the practical part, which presents the industry in all its aspects from the arrangement of electro-plating establishments to actual methods used in the deposition of various metals. It is here that the plater finds a treasury of practice that he may turn to direct account in his business. As a work of reference it is unapproached by any similar work in our language. The formulas alone are worth many times the cost of the book to anyone interested in plating and other metal finishing methods. 863 pages. 185 illustrations. Price **$7.50**

FUEL

COMBUSTION OF COAL AND THE PREVENTION OF SMOKE. By Wm. M. Barr.

This book has been prepared with special reference to the generation of heat by the combustion of the common fuels found in the United States, and deals particularly with the conditions necessary to the economic and smokeless combustion of bituminous coals in Stationary and Locomotive Steam Boilers.

The presentation of this important subject is systematic and progressive. The arrangement of the book is in a series of practical questions to which are appended accurate answers, which describe in language, free from technicalities, the several processes involved in the furnace combustion of American fuels; it clearly states the essential requisites for perfect combustion, and points out the best methods for furnace construction for obtaining the greatest quantity of heat from any given quality of coal. 5th Edition. Nearly 350 pages, fully illustrated. Price, . . . **$1.50**

GAS AND OIL ENGINES

THE GASOLINE ENGINE ON THE FARM: ITS OPERATION, REPAIR AND USES. By Xeno W. Putnam.

This is a practical treatise on the Gasoline and Kerosene Engine intended for the man who wants to know just how to manage his engine and how to apply it to all kinds of farm work to the best advantage.

This book abounds with hints and helps for the farm and suggestions for the home and housewife. There is so much of value in this book that it is impossible to adequately describe it in such small space. Suffice to say that it is the kind of a book every farmer will appreciate and every farm home ought to have. Includes selecting the most suitable engine for farm work, its most convenient and efficient installation, with chapters on troubles, their remedies, and how to avoid them. The care and management of the farm tractor in plowing, harrowing, harvesting and road grading are fully covered; also plain directions are given for handling the tractor on the road. Special attention is given to relieving farm life of its drudgery by applying power to the disagreeable small tasks which must otherwise be done by hand. Many home-made contrivances for cutting wood, supplying kitchen, garden, and barn with water, loading, hauling and unloading hay, delivering grain to the bins or the feed trough are included; also full directions for making the engine milk the cows, churn, wash, sweep the house and clean the windows, etc. Very fully illustrated with drawings of working parts and cuts showing Stationary, Portable and Tractor Engines doing all kinds of farm work. All money-making farms utilize power. Learn how to utilize power by reading the pages of this book. It is an aid to the result getter, invaluable to the up-to-date farmer, student, blacksmith, implement dealer and, in fact, all who can apply practical knowledge of stationary gasoline engines or gas tractors to advantage. 530 pages. Nearly 180 engravings. Price **$3.00**

GASOLINE ENGINES: THEIR OPERATION, USE AND CARE. By A. Hyatt Verrill.

The simplest, latest and most comprehensive popular work published on Gasoline Engines, describing what the Gasoline Engine is; its construction and operation; how to install it; how to select it; how to use it and how to remedy troubles encountered. Intended for Owners, Operators and Users of Gasoline Motors of all kinds. This work fully describes and illustrates the various types of Gasoline Engines used in Motor Boats, Motor Vehicles and Stationary Work. The parts, accessories and appliances are described, with chapters on ignition, fuel, lubrication, operation and engine troubles. Special attention is given to the care, operation and repair of motors, with useful hints and suggestions on emergency repairs and makeshifts. A complete glossary of technical terms and an alphabetically arranged table of troubles and their symptoms form most valuable and unique features of this manual. Nearly every illustration in the book is original, having been made by the author. Every page is full of interest and value. A book which you cannot afford to be without. 275 pages. 152 specially made engravings. Price **$2.00**

GAS ENGINE CONSTRUCTION, OR HOW TO BUILD A HALF-HORSE-POWER GAS ENGINE. By Parsell and Weed.

A practical treatise of 300 pages describing the theory and principles of the action of Gas Engines of various types and the design and construction of a half-horse-power Gas Engine, with illustrations of the work in actual progress, together with the dimensioned working drawings, giving clearly the sizes of the various details; for the student, the scientific investigator, and the amateur mechanic. This book treats of the subject more from the standpoint of practice than that of theory. The principles of operation of Gas Engines are clearly and simply described, and then the actual construction of a half-horse-power engine is taken up, step by step, showing in detail the making of the Gas Engine. 3d Edition. 300 pages. Price **$3.00**

HOW TO RUN AND INSTALL GASOLINE ENGINES. By C. Von Culin.

Revised and enlarged edition just issued. The object of this little book is to furnish a pocket instructor for the beginner, the busy man who uses an engine for pleasure or profit, but who does not have the time or inclination for a technical book, but simply to thoroughly understand how to properly operate, install and care for his own engine. The index refers to each trouble, remedy, and subject alphabetically. Being a quick reference to find the cause, remedy and prevention for troubles, and to become an expert with his own engine. Pocket size. Paper binding. Price . . **25 cents**

GEARING AND CAMS

CHANGE GEAR DEVICES. By Oscar E. Perrigo.

A practical book for every designer, draftsman, and mechanic interested in the invention and development of the devices for feed changes on the different machines requiring such mechanism. All the necessary information on this subject is taken up, analyzed, classified, sifted, and concentrated for the use of busy men who have not the time to go through the masses of irrelevant matter with which such a subject is usually encumbered and select such information as will be useful to them.
It shows just what has been done, how it has been done, when it was done, and who did it. It saves time in hunting up patent records and re-inventing old ideas. 3rd Edition. 101 pages **$1.50**

CAMS, LAYOUT AND DRAFTING. By Louis Rouillon.

A practical work on various forms of cams and their design including useful suggestions for laying out and drafting typical forms. Contents: 1. Laying Out Cams. 2. Drafting Cam Curve. 3. Heart Shape Cam. 4. Positive Motion Cam. 5. Irregular Motion Cam. 6. Toe and Lift Cam. 7. Double Contact Cam. 8. Cylindrical Cam. 9. Cam Belt Shifter. 10. Gas Engine Cams. 11. Cam for Mushroom Follower. 12. Non-reversible Cams. 13. Reversible Cam. 14. Variable Motion. 15. Harmonic Motion. 16. Motion Diagram. 17. Flat Reciprocating Cam. 18. Sleeve Cam. 19. Face and Drum Cams. 20. Device for Cam Drafting. Revised and Enlarged Edition. Paper cover. Price . . . . . **75 cents**

DATE DUE

GAYLORD	PRINTED IN U.S.A.

LIBRARY
College of St. Scholastica
DULUTH, MINN.